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THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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PLASTIC PLANES

By JOHN DELMONTE, Technical Director, Plastics Industries Technical Institute. (From *Machine Design*, Vol. 12, No. 10, October, 1940, pp. 50-51 and 89-90).

AIRPLANE fuselages and wing assemblies of laminated phenolic plastics are but one indication of the recently reawakened interest in the use of plywood construction, particularly in the field of transportation. Airplane manufacturers are well aware of the strength-weight advantages of wood construction and also of the ravages of outdoor exposure which include fungi decay in the wood and loss of shear strength in the bonded joints due, among other things, to lack of waterproof qualities in the bonding agent. The advantages of the newer plastic materials in plywood construction lie not only in the improvement of the physical and chemical properties of the finished product, but also in the saving in time of manufacture and the floor space requirements for conducting the bonding of the plywood.

Various techniques which have been developed for the bonding of plywood may be divided into several classifications:

(1) Application of cold-setting adhesives.

(2) Hot bonding of plywood laminations at low pressures.

(3) Hot bonding of plywood laminations at high pressures, with increased resin content.

Cold-Setting Adhesives.

In applying cold-setting adhesives to plywood construction, it has been desirable to use a number of water-soluble materials which set hard upon drying. Various glues such as casein, animal, starch, albumen, etc., have been employed. The usual procedure is to apply the adhesive as uniformly as possible and under a clamping pressure bring the surfaces together in intimate contact.

Resin Hardened by Catalyst.

One of the more recent developments in cold-setting adhesives is the application of a urea-formaldehyde synthetic resin, which may be hardened in a relatively short time by the application of the proper catalyst. This is accomplished without an increase in temperature, though this same synthetic resin may be hardened by heat without catalyst. In its pure form, stronger joints are formed which are more resistant to water than the other adhesives mentioned in the preceding paragraph. However, it is usually extended with wheat or rye flour to lower the cost. While the strength and water resistance remains superior to other types for a considerable amount of dilution with an extender, increasing proportions will lower the strength and the cost. Depending upon the nature of the veneers being bonded and for what purpose they are intended, it is possible to adjust a suitable ratio and attain a certain strength at a specified cost.

Hot Bonding at Low Pressures.

Thermosetting plastic materials, such as phenol-formaldehyde and urea-formaldehyde, attain their best physical properties when cured under heat and pressure, polymerizing to a hard, infusible structure which is water resistant and very strong. Best results have been obtained with the more recent technique of applying the phenolic resin in a thin film form. Dry appli-

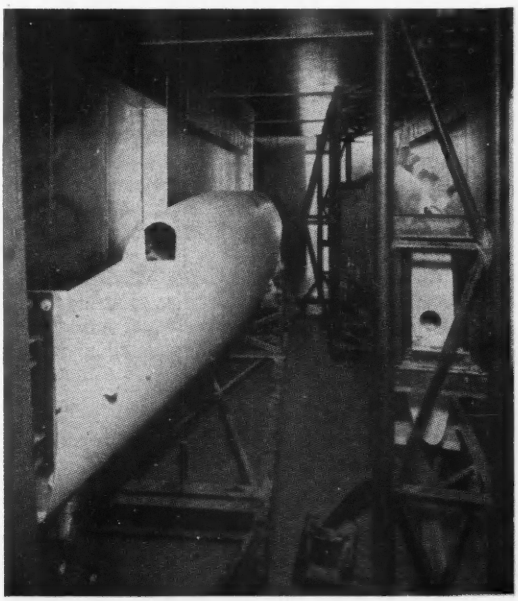


Fig. 1

cation of the film affords the big advantage that uniform distribution of the plastic material is instantly obtained.

In the case of aircraft manufacturers, special techniques have been developed in which the veneers are assembled over low-cost dies and forms, with the thermosetting resin sprayed on or applied in film form between each wood veneer (usually spruce). The composite assembly is cured under heat in a tank where pressures between 50-150 lbs. per square inch may be obtained. Pressures and temperature that are employed are dependent not only on the type of wood, but also the moisture content of the wood. A typical wing and fuselage assembly which are developed from spruce veneers and thermosetting phenolic plastic adhesives are shown in Fig. 1.

Density of Wood Unchanged.

In plastic airplane constructions, the density of the wood is not altered appreciably inasmuch as little of the plastic material is used, and this does not penetrate deeply at the pressures employed. However, there is little doubt of the superiority of the plywood bonded with these materials over the naturally occurring adhesives with respect to water resistance and shear strength. Mould and fungus growth which limited the utility of the earlier types are also entirely overcome.

Mention should be made of various other plastic materials employed in plywood construction such as the zinc-chloride, urea-formaldehyde types and the straight urea-formaldehyde resins, both thermosetting in nature.

Another significant feature of bonding with plastic materials which are thermosetting, is that the time for cure is a matter of minutes, most veneering jobs being completed in less than one-half hour; usually 3 to 15 minutes.

Hot Bonding at High Pressures.

They may perhaps more strictly be called plastic materials than the other plywood constructions, since a much greater ratio of resin to plywood is present. Developments have been pursued along several channels:

(1) Alternating thin (0.021 inch) wood veneers with more than one resin film and pressing at pressures up to 1,500 lbs. per sq. in.

(2) Impregnating spruce or birch veneers with water soluble phenolics, and curing under heat and pressure to convert the phenolic plastic to an infusible, insoluble form.

(3) Impregnating veneers with alcohol soluble phenolics, and laminating under heat and pressure up to 3,000 lbs. per sq. in.

Strength Proportional to Density.

In general, the strength of the plywood appears to be proportional to the density of the finished compressed material, as well as being dependent on the proportion of the synthetic resin present. Tests, however, indicate substantial gains in strength, depending upon the proportion of resin to plywood, the nature of the wood, and the pressure applied. It has been reported that in some instances the increase of tensile strength over the solid wood is as much as 127% when pressed under pressures of 1,500 lbs. per sq. in. The impregnation with water soluble phenolics improves the life resistance of the wood, though gains in physical strength are not appreciable.

The last procedure (3) yields what amounts to a laminated phenolic plastic material, because the identity of the wood laminations is almost lost in the formation of a composite plastic structure reinforced with wood fibres. This material possesses a specific gravity of about 1.3, whereas the plastic woods bonded by the low pressure methods are around 0.6 to 0.8. Under the high pressures employed there is a considerable reduction in thickness, with the resulting crushing of the cellulose structure.

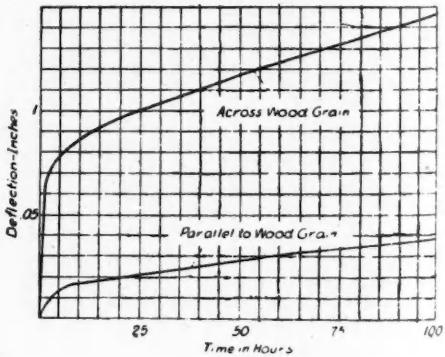


Fig. 2.

Physical properties therefore, depend greatly upon the phenolic plastic molecular structure, as in moulded and other laminated structures. Nevertheless, when samples of laminated wood veneers prepared by this procedure are examined for creep and cold flow, the influence of the wood grain direction is marked. For example, in the accompanying curves, Fig. 2, the creep is much greater when the direction of stress is across rather than parallel to the wood grains.

A CONTRIBUTION TO THE QUESTION OF INCREASING THE EFFICIENCY OF MACHINE WORKSHOPS

By Reg. Rat Dr. Ing. Ernst Franke, V.D.I., Berlin. (From *Die Werkzeugmaschine*, Vol. 44, No. 1, pp. 9-12).

It appears to be of great importance to consider and estimate the values of results obtained by the observation of "great numbers," with respect to increase the efficiency of mechanical plants.

The method, based upon the rules of mathematical-statistics, consists of representing graphically the frequency of a certain occurrence, and hence, to predetermine the probability of an expected result. In the "frequency" graph —which is usually of an irregular form,—a "standard value field" can be drawn, and from this the frequency corresponding to a certain factor can be easily found. The system has found a wide range of application, especially in metallurgy, where the influence of the constituents of an alloy upon the final characteristics of the alloy is determined by examining a great number of cases.

In machine workshops no use has been made so far of this system, and in what follows we are going to apply this method to workshops and processes. From the many possible applications of this system, we select a few which appear to be of principal interest.

Figs. 1 and 2 show how the cutting speed corresponding to two substances and two different cutting tools can be established. Fig. 1 shows the frequency curve for two substances, A and B, on the basis of a cutting tool made of carbon steel. Fig. 2 gives similarly the frequencies plotted against cutting speed for the same substances, when a high speed steel tool is employed.

As a rule it will be desirous to regard as standard value not only the value given by the peak of the graph, i.e. the value corresponding to the greatest frequency, but also some values to the right and left from it. The area enclosed by these limiting co-ordinates, and the line passing through the highest point of the graph, gives the "field of standard value." It should be mentioned that the limiting ordinates must not lie equidistant from the maximum ordinate, but they should enclose such values as are still occurring with a considerably great frequency. The dependence of the area of the field of standard value from the shape of the curve is well illustrated in Fig. 1. Although the frequencies of the limiting values do not differ

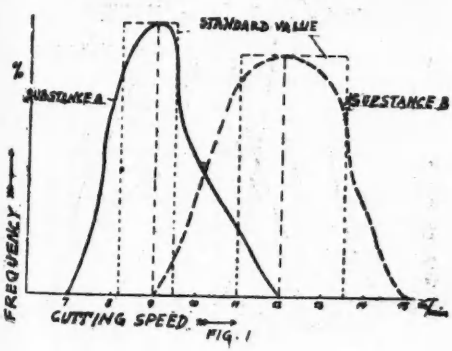


FIG. 1

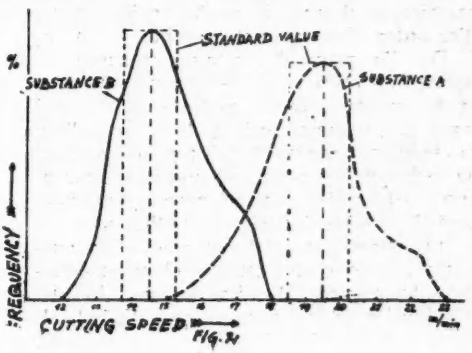


FIG. 2

considerably in case of A and B, yet the area of the field of standard value for B is considerably wider than that of A.

The highest obtainable value for the frequency depends to a certain extent also upon the actual working condition of the machine. If a graph were plotted for each machine corresponding to the frequency of the cutting speeds, under similar conditions, then the deviations (due to the machine) would become immediately apparent. Thus it could be determined which of the machines is in the best working condition.

Next we will illustrate how this method can be employed to determine approximately the maximum working life of a certain type of machine or tool. In this case the working life of individual tools or machines is plotted against the frequency. This graph would clearly show after what elapse of time a certain type of tool or machine becomes unserviceable. Hence, it can be determined if the best or worst products of a firm have been delivered.

Fig. 3 illustrates how this method is employed to determine the time required by various types of machines to produce the same work piece. The frequency curve corresponding to machine A shows the most favourable results. This curve is almost symmetrical (ideal curve), and its highest ordinate corresponds to the least time required compared with the other curves. Also the range of time (enclosed between the ends of the frequency curve) is the least among the four curves. Again machine D must be regarded as the most inferior, since the highest frequency of the latter machine corresponds to 82 minutes, compared with 50 minutes of the machine A. Also the range of time is the largest with this machine, i.e. the machine works very irregularly. The order of merit of the machines is A, B, C, D. The practical conclusion which can be drawn from these results is obvious. As most of the operations can be performed on several types of machines, such as lathe or milling machine, etc., results of each type of operation on each type of machine should be plotted in order to determine for which purpose a machine could be used with the greatest efficiency.

In order to increase the efficiency of a manufacture, a very good method is obtained sometimes by reducing the time required by the individual machine parts to pass through all the workshops. For this purpose it is required to operate the workshops on progressive method of manufacturing, which does not mean necessarily that a special conveying apparatus is needed. Before the manufacturing process of a certain article is started it must be predetermined, which will be the most suitable method to follow during the production. It must be prevented that work pieces are left lying about between the individual phases of operation. Many other factors must also be taken into account such as uninterrupted working of the men, immediate repair of breakdowns, etc. Further, the "waste time" must be kept as low as possible. Various types of frequency curves for different troubles, etc., must be prepared, which will help to choose the best manufacturing process.

It should be pointed out, however, that machines requiring the least time to finish a work piece are not necessarily the most economical ones. Capital investment, working life of the machine, power used, etc., together will decide upon the question of economy. But from the point of view of improving the efficiency of a workshop, especially in war-time, the question of economy is not the most important.

Fig. 4 illustrates how the frequency curve can be used to find the most efficient workmen. The efficiency of a workman must be judged on the basis of time required to finish the same work compared with others under comparable conditions. Three workmen are considered in Fig. 4. The range of time to finish a certain work piece is very much the same for the workmen A and B—being of the order of 4

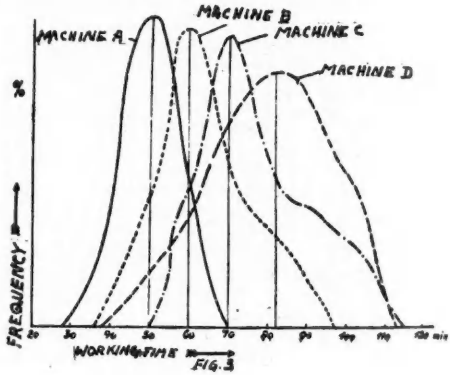
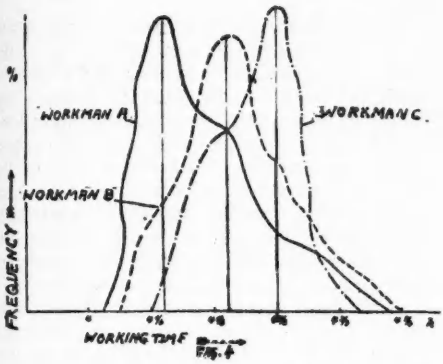


FIG. 3



hours 2 minutes to 4 hours 48 minutes in case of A and 4 hours 5 minutes to 4 hours 50 minutes in case of B. In case of C, the time range is the smallest, being 4 hours 10 minutes to 4 hours 43 minutes. In spite of this fact, the efficiency of C is the least, since the maximum frequency ordinate is situated at the longest time required for the three cases. Again it can be seen from the graph that the frequency curve in case of B is wider on the top than in case of A, and also that the maximum frequency is to the right (more time required) from that of A. The curve of A shows only one disadvantage compared with B and that is that the curve is very unsymmetrical. However, the peak value of the frequency curve has a higher value in case of A, hence it can be concluded that A is the most efficient workman.

If the cost of labour is to be compared in case of hour wages and wages paid per finished pieces, then the procedure is as follows. The frequency curves are plotted on the basis of working time. Assuming that the range of time lies between 26 and 36 minutes, and that the maximum frequency occurs at 30 minutes, and further assuming that the greater number of cases are lying to the right of the maximum ordinate, than the average time required to finish a work piece will be slightly more than 30 minutes. From these results, it can be easily calculated which type of payment is more economical from the point of view of the manufacturer.

The examples given in this article do not cover the entire field of application of this system. The limits of application can be extended practically indefinitely. Sometimes the curves will be very irregular and unsymmetrical. Many factors will account for this. The ideal curve is symmetrical and can be approached if more cases are considered, and disturbing factors avoided as far as possible.

The frequency curves have another important field of operation with respect to workshop efficiency. They show whether the individual workshops are working efficiently and economically. By comparing the frequency curves of various workshops, it can be ascertained which shows the most troubles and faults, and hence, they can be eliminated in due time.

DIESEL-ELECTRIC LOCOMOTIVES

By H. V. GILL. (From *Mechanical Engineering*, Vol. 62, No. 11, November, 1940, pp. 820-821).

SINCE 1935 the Atchinson, Topeka, & Sante Fe Railway Co. has placed in service 41 Diesel-electric switching locomotives and 18 Diesel-electric high-speed passenger locomotives with a total power of 73,140 h.p.

The passenger-locomotive units are each powered with two 12-cyl. V-type, two-cycle Diesel engines, the horse power rating being 1,800 to 2,000 h.p. per unit, and the maximum speed with a 25:52 gear ratio is 117 m.p.h. These units have worked with an availability of 95.3% to June 1, 1940. Switching locomotives are powered with either the four-cycle or two-cycle Diesel engine. They have been available 94.3% of the time during 1939. This availability of Diesel-electric locomotives is possible because they do not require extensive repairs, frequent watering or fueling, boiler washing, or fire cleaning. Because of the swivel truck and long wheel base, the elimination of reciprocating parts, and low centre of gravity, the Diesel locomotive is easy on the track and will operate at high sustained speeds on fast schedules.

In a Diesel-electric switching locomotive, all of the weight is carried on the driving wheels, which gives an effective return for locomotive weight. Since the average speed for switching operations rarely exceeds 6 or 7 m.p.h., by selecting the proper gear ratio between the traction motor and power axle (about 4:1), the Diesel-electric switcher will handle the work of a steam locomotive which has a horse power rating of approximately 2½ times that of the Diesel locomotive.

The following table gives the operating cost of 4,000 h.p. Diesel-electric locomotives in high-speed passenger service. (Year 1939).

	Cost per loco. mile
Fuel	$0.123
Locomotive repairs, labour and material	$0.137
Lubrication	$0.011
Supplies	$0.007
Total cost per mile	$0.278

COST OF OPERATION PER SERVICE HOUR IN SWITCHING SERVICE

	600hp. 2-cycle Diesel electric dollars	600hp. 4-cycle Diesel electric dollars	1000hp. 2-cycle Diesel electric dollars	1000hp. 4-cycle Diesel electric dollars	Steam locos. Sante Fe 566 class dollars
Fuel	0.199	0.290	0.261	0.282	1.53
Locom. repairs, labour and material	0.286	0.143	0.336	0.119	1.12
Estimated cost of general repairs	0.250	0.250	0.250	0.250	—
Enginehouse expense	0.060	0.046	0.028	0.026	1.38
Lubrication	0.073	0.033	0.045	0.022	0.06
Supplies	0.009	0.013	0.014	0.021	0.04
Water	—	—	—	—	0.30
Total per service hour	0.877	0.775	0.934	0.720	4.43

At the present time, the electric transmission is one of the limiting factors in so far as continuous operation on heavy grades is concerned. This is due to the necessity of dissipating the thermal losses from the generators and traction motors. Another limiting factor which interferes with continuous operation of the Diesel-electric locomotive on heavy grades during hot weather is the dissipation of the tremendous amount of heat generated by the Diesel engines, which is brought about by space limitations, weight-per-axle limitations, and the power required to drive cooling apparatus.

Approximately 63% of the repair charges to Diesel locomotives are for materials. Since the road locomotives, which are powered with two-cycle Diesel engines, are operating under a load factor of about 60%, trouble has been experienced with the engines. In fact, the maintenance expense comprises about 50% of the total locomotive repair costs. In switching service, locomotives are assigned to three shifts, 24 hours-a-day service, in order to take full advantage of the savings possible with this type of power.

Switching locomotives are fueled two or three times a week, while road locomotives run more than 600 miles between fuel and water stations. The use of air filters and oil filters has increased lubricating oil drain periods from 5,000 miles to 100,000 miles of service for the road units. In switching service, crankcase lubricating oil is changed every three to six months of service.

Cylinder liners that were worn 0.050 to 0.060 in. in about 60,000 miles are reconditioned for use again. Cylinder heads are reconditioned or repaired every 100,000 miles by means of welding. Piston assemblies are removed for inspection every 100,000 miles and replaced after 220,000 miles of service. This mileage will be greatly increased as new type pistons replace the older designs. Air for engine radiators is now carried through ducts, eliminating dirt from this source getting into the engine rooms.

Wheels on the locomotives have been greatly improved. The service life of present wheels is about 250,000 miles with about 84,000 miles between machinings. During the short development period through which the Diesel locomotive has gone, there has been a transition from a single-engine-powered car of 600 h.p. to locomotive units having two Diesel engines of 1,000 h.p. each, and operation of these units in multiples of two or three units making a Diesel locomotive of 4,000 to 6,000 h.p.

NEW SWISS MACHINE TOOLS

By ING. DR. H. BRANDENBERGER. (From *Schweizerische Bauzeitung*, Vol. 116, No. 11, September, 1940, pp. 120-124).

THIS article describes the latest development of Swiss Machine Tools since the last Basle Fair.

General.

The beds of the machines show a box-shaped design for rigidity. The design of the machines is extremely compact. Arrangements to carry away tool coolants and chips are carefully designed. The slides can be moved by hand and are also provided with automatic feed and fast travel. Rotable cutting heads are provided and stops for each position of the head. Releasing device is fitted to the automatic feed controls. Built-in push-button controlled motors simplify greatly the general design of the machines. Hydraulic transmissions are frequently made use of, driven by gear pumps, which also control the central lubrication system. Endlessly woven fabric belts are frequently used to drive extra high speed spindles. Control handles, etc., are arranged on saddles rather than centrally to simplify handling of the machines from the man's working position. Further details will be discussed in connection with the individual machines.

Fig. 1 shows a turret lathe for bar jobs. The turret is supported by a slide arranged behind the work piece for rigidity. The hexagonal turret head has automatic feed, and mechanical change for the six tool-holders. The cross saddle has a square tool-holder and four longitudinal and transverse feeds, a releasing device, and an adjustable cross-head stop. The sides of the bed carry a sliding drill head which, when fixed in position and fitted with a centre, can be used as a tail stock. For reversing the spindle a " Herbert " disc clutch is built in the head stock. Altogether 84 different speeds can be obtained.

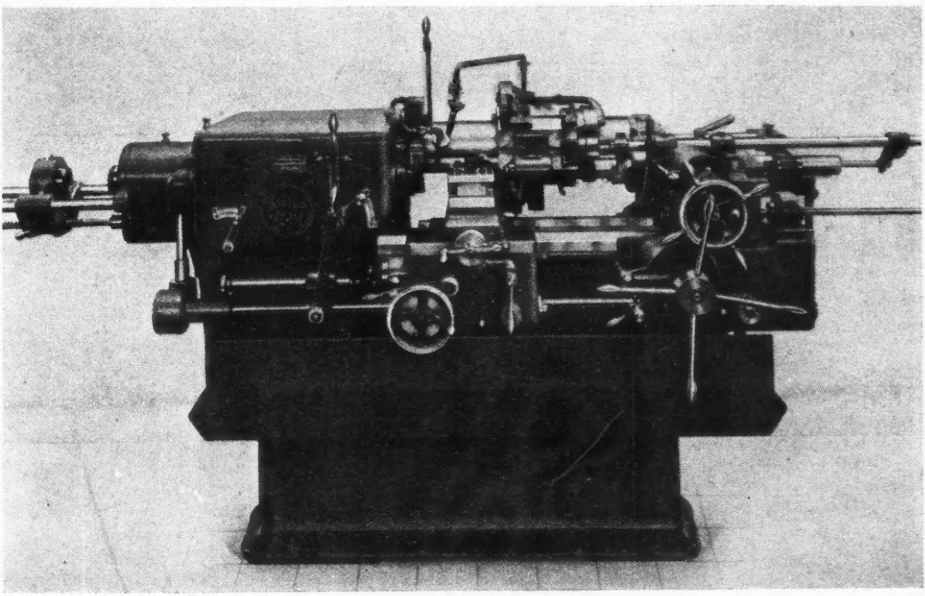


Fig. 1.

The " Original-Schaerer Turret Lathe for Chuck Jobs," shown in Fig. 2, has a wide and high bed, heavily cross-ribbed for rigidity. It rests on a pedestal which serves as an oil tank. The head stock lies in a deep groove in the bed. A knee inclined backwards allows working of bulky work pieces up to 740 mm. diameter. The head stock has a " Radiax " drive, consisting of an oil controlled sliding pinion, which can engage a seven-stepped wheel. The valve controlling the flow of oil in the cylinder is operated by a vertical lever, by means of which the pinion is brought to its outermost position. The lever is then adjusted to the required spindle speed, and the radial bracket carrying the pinion swings over to bring the pinion to the engaging position. A segment plate has a stop for each engagement position, in which the radial bracket is held fast, thus securing the pinion in position and preventing incorrect contact. 21 spindle speeds can be obtained.

The driving pinions of the main spindle are situated on the front of the head stock so that the driving force is downwards on the spindle bearings, which improves the smoothness of operation. The main slide runs in " V " grooves and on flat guides situated on the front of the bed. The turret lathe slide 900 mm. in length has two guiding grooves not at the same height, hence, it is inclined on the slide so that the long bars can pass over the cross slide when the latter is used. The turret slide is fitted with a constant speed fast travel. A thread cutting device can be fitted to the machine, and a device on to the front of the main slide for conical rotation.

The " Miniflex Universal " milling machine (Fig. 3), has welded supports and a very rigid frame construction. The transverse bed moves in four diagonally arranged supporting guides. The milling table can be inclined at 45° to either side. One hand wheel controls the movements of the milling table by hand, automatic feed, or quick traverse. In order to make the table free for bulky work pieces, the support, usually connected to the back stops of the overhead arm, can be easily dismantled. The milling spindle is driven by a 7 h.p. Wendel motor, and a 2 h.p. motor provides the drive for the feed through a " V " belt. The face plate is embedded in the breast of the column,

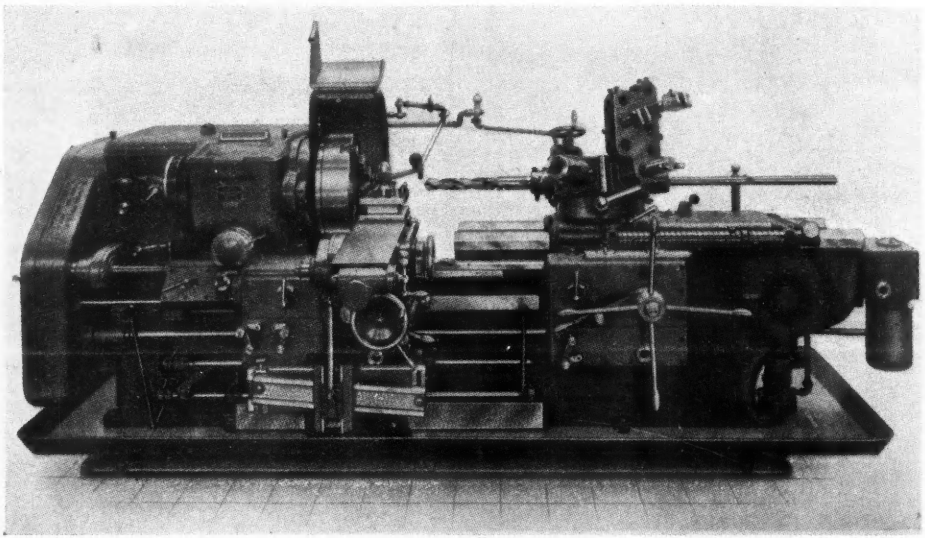


Fig. 2.

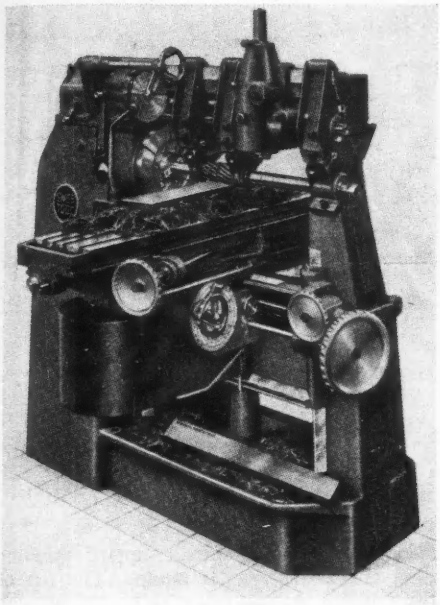


Fig. 3.

and is provided with four bolts on the front to fix the tool, and fitted with internal teeth at the rear for drive.

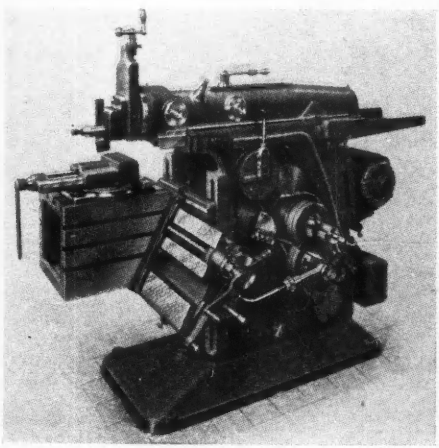


Fig. 4.

The "Schaerer High Speed Shaper" (Fig. 4), is fitted with a Radiax drive, controlled by oil gear. 12 cutting speeds can be obtained on the machine. When brought to rest, a brake stops the ram almost instantaneously. The tool-holder has five vertical feeds, adjustable at any position of the ram.

Fig. 5 shows the "Benninger" Universal short-thread milling machine, the head stock of which can swing with a maximum amplitude of 15° on the slide. The work piece spindle has a bore of 160 mm., and is lined with hardened and ground conical ring to take the collet chuck. At the rear it is fitted with a guide to control the screw pitch.

The semi-automatic Universal copying-milling machine, type "Billeter" (Fig. 6) is mainly used in the watchmaking industry. All types of grooves and transitions of clockwork plates can be milled on the machine. The machine consists of a column on which two arms can swing around an axis. One arm carries the work piece, the other the spindle. It swings over two curved discs against which two bolts are pressed by means of springs. The curved discs are driven through a worm gear by a special motor. A bell shaped disc is also provided, which controls the fixing plate. The cutter is not adjustable in the vertical direction, hence, the work piece must be adjusted by the bell shaped disc. The cutter speed is about 6,000 to 15,000 r.p.m.

Fig. 7 shows the internal grinding machine type "Voumard" used for internal grinding of cylindrical and conical work pieces. The grinding spindle slide moves forward and backward along a maximum stroke of 120 mm., the speed is steplessly adjusted from 0 to 4

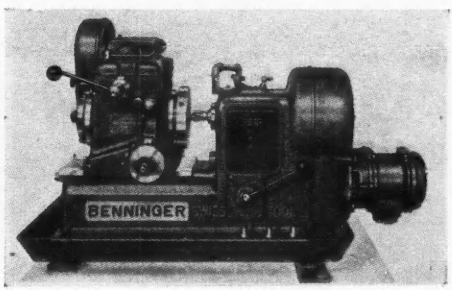


Fig. 5.

m./min. The spindle is driven through a pair of four stepped discs at 10,000 to 35,000 r.p.m. The adjustment of the grinding disc is automatic and is indicated on a scale. The headstock can be turned through an angle of 90° and can be radially moved on the cross-slide.

A universal tool grinding machine is shown in Fig. 8. All transmissions in the columns are eliminated due to the arrangement of the five motors for the machine table, the grinding

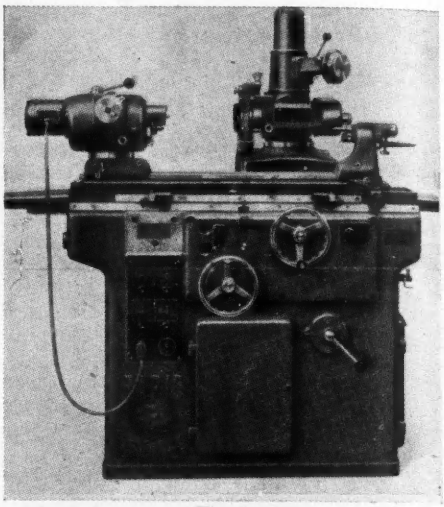


Fig. 8.

spindle, the grinding spindle support, grinding disc, and cooling water pump. The top of the grinding standard can be turned through 360°. The grinding spindle can be adjusted to

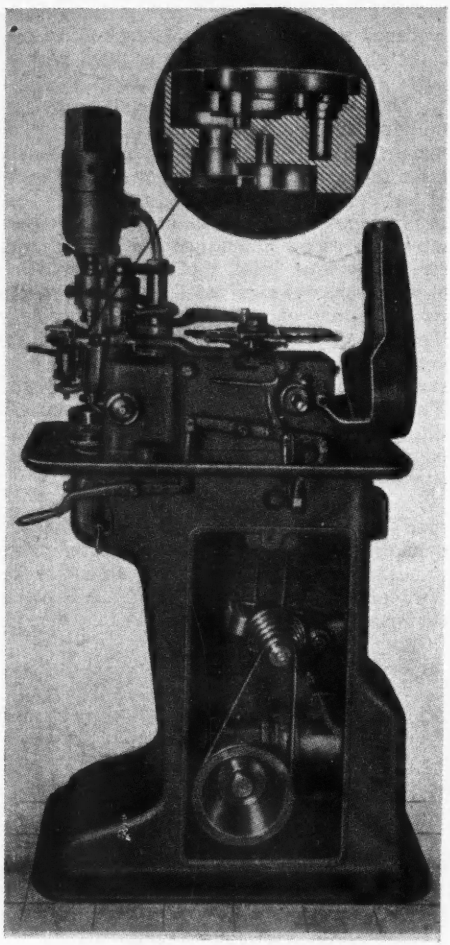


Fig. 6.

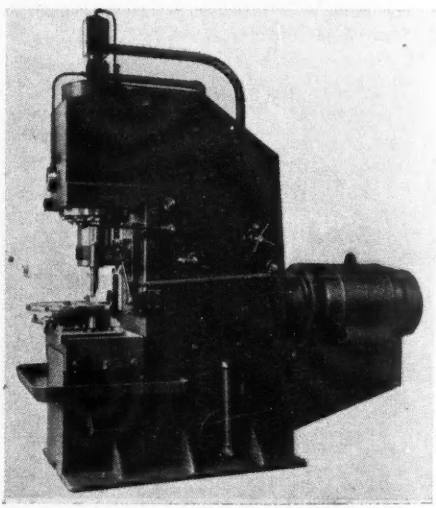


Fig. 9.

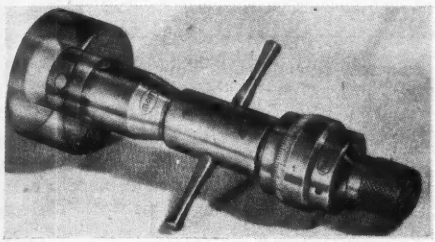


Fig. 10

make an angle with the horizontal plane. The table has a rotating top part, which swings through 90°. Stepless regulation of the table is arranged. The head stock can be adjusted for six speeds of the work piece. By pushing a knob, the change over from fixed to rotating centre can be affected.

Fig. 9 shows the oil-pressure high-speed-pressing machine. The body is built up with electrically welded steel plates. The pressure is produced by an internal gear pump or by a combination of gear pump and reciprocating pump. The stroke can be regulated at any position, hence, the table and the top part of the press are at a fixed height. Three types of operation of the machine can be distinguished :

(1) At partial stroke the ram is governed by hand or by a pedal. This working is suitable for straightening, riveting and stamping.

(2) Individual strokes are started by hand, but the return stroke follows automatically. This method is suitable for punching, drawing and broaching.

(3) Continuous operation is suitable for drawing, pressing, groove cutting to form internal teeth.

A new measuring instrument, the " Kaliber-Micro-Mag " is shown in Fig. 10. This instrument can read accurately up to $^1/_{1000}$ mm. within a range of standard diameter variations of -0.1 to $+0.05$. A bore is measured by means of axial movement of a conical needle, which forces three radially placed pins against the bore to be measured. The needle is moved by a spring, while the calibrating screw follows up to a positive full division. During the introduction of the needle in the bore, the three pins are withdrawn. The diameter of the bore can be measured at any required depth. Bores up to 40 mm. diameter and 110 mm. length can be measured.

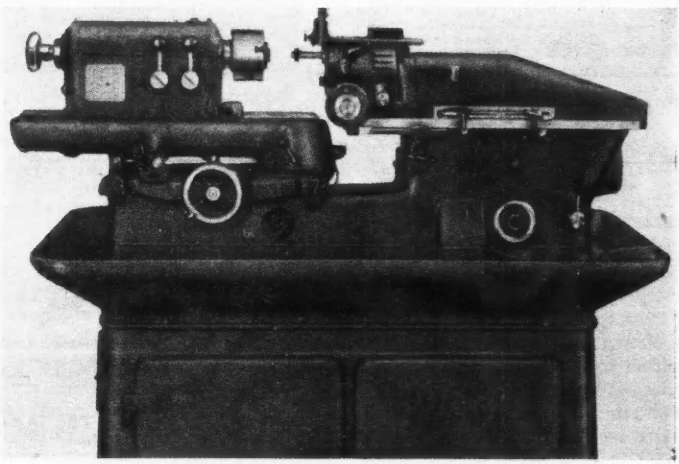


Fig. 7.

DEVELOPMENT OF THE TECHNIQUE OF RIVETING LIGHT-METAL AIRPLANE CONSTRUCTIONS

By PROF. DR. A. VON ZEERLEDER. (From *Flugwehr und Technik*, Vol. 2, No. 5-6, May-June, 1940, pp. 120-123).

RIVETING sheet metal joints is more common practice in airplane construction than welding, since the latter method is inevitably accompanied by high temperatures, to which machine parts can not always be exposed.

Various types of rivets are illustrated in Fig. 1. Those from (a) to (e) are rarely used on the outer span of the aircraft because the protruding rivet heads would considerably increase the air resistance of the aircraft.

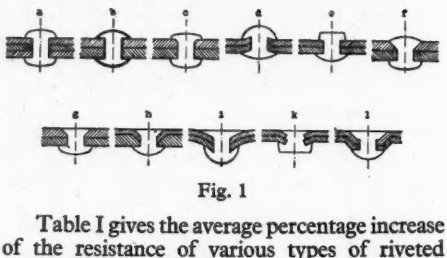


Fig. 1

Table I gives the average percentage increase of the resistance of various types of riveted surfaces compared with that of a flat surface when towed through water at speeds of 10 to 30 m./sec. (The riveting covers about 50% of the exposed surface.)

TYPE OF RIVET	INCREASE OF WATER RES.
	= 10%
	15 to 20%
	25 to 28%

The tendency of modern technique is to process rivets completely flush with the sheet metal, such as shown in Fig. 1, from (g) to (l). The metal is either countersunk, to receive the rivet head (see g), which reduces the strength of the joint, or else the edge of the holes through the sheet metal is bent down to accommodate the rivet head. The frictional resistance of the edges of the sheet metal improves the strength characteristics of the latter type of riveting.

A difficulty often arises in airplane construction and particularly in repair work, if riveting must be performed with access to one side of the work piece only. Several methods are available, one of which is shown in Fig. 2. A tool with springs on its underside is introduced in the tube (this method is mainly employed for riveting to tubes). Hammer blows on the rivet head push the anvil downward and the rebound of the springs pushes it back against the end of the rivet inside the tube. These repeated impacts eventually close the rivet. In

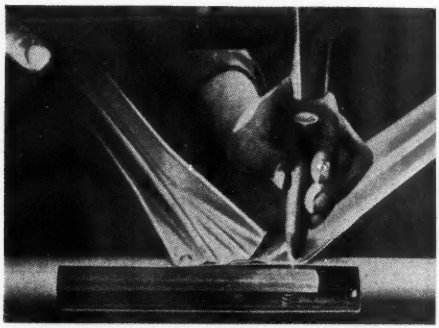


Fig. 2

other cases, when riveting is performed from one side of the work piece, the method illustrated in Fig. 3 is employed. Principally, it consists of using hollow shaft rivets, through which a suitably shaped instrument is pushed.

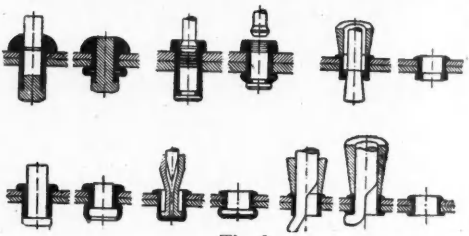


Fig. 3

The rivet head is held firmly against the sheet metal, and simultaneously the inner sleeve of the instrument is pulled in the opposite direction, causing the hidden end of the rivet to be expanded. Hollow rivets have considerably less resistance against shearing forces than solid rivets, and further they are not water-tight.

The newest development is an "explosive rivet," the principle of which was so startling that engineers doubted its practical value, practice, however, has proved these rivets to be satisfactory from every point of view. The inventors succeeded in producing an explosive which detonates when heated to between 130 to 150° C. At the same time neither the explosive nor the combustion products have any corrosive effect on the material of the rivets or machine part. The ignition of the explosive is caused by heating the rivets to about 150° C. by pressing an electric heater on the rivet head. Fig. 4 shows the relation between heater temperature and the time required until the explosion takes place. In practice the explosion follows in about 2 to 3 secs.

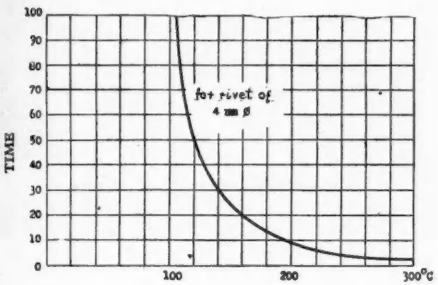
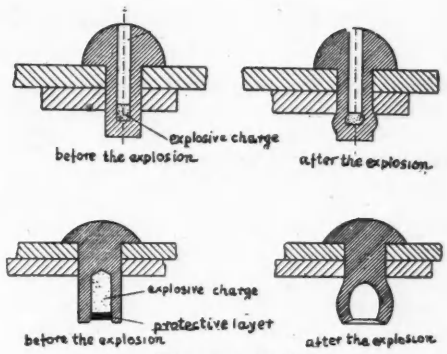


Fig. 4

Fig. 5a shows the first type of explosive rivet. A hole was drilled in the rivet from the top of the rivet head and loaded with the explosive. With this design, the length of the rivet shafts had to correspond to the thickness of the sheet metals to be joined, and it was found that if too much explosive was used the closed end of the rivet was blown off. With the development of powerful explosives, the hole could be drilled in the rivet from the shaft end, as shown in Fig. 5b. The bore in the rivet is half the shaft diameter, and is three-quarters filled with explosive and covered with a special varnish to protect the explosive against moisture



Figs. 5a and 5b

and leakage. The explosion not only causes the "spread" of the rivet, but also expands the rivet shaft (see Fig. 6). This expansion is not so considerable as with ordinary cold riveting, and the rivet holes must be drilled more accurately to arrange for an initial clearance of approximately 0.05 to 0.1 mm. In order to ensure this fit, the rivet holes are drilled 2 to 3 mm. less than that of the rivet shaft, and than reamed to the exact dimension. The surface of the rivets is protected against corrosive attack by an anodising treatment.

If the interior of the work piece to be riveted is so narrow that the opposite side has less than the diameter of the rivet clear from the end of the rivet, a steel sheet is introduced between the rivet and the opposite side to protect the latter from possible damage due to the explosion.

The advantages of the explosive rivets can be summarised as follows:

(1) Access only to one side of the machine part is needed.

(2) Strength of the rivets is not less than that of ordinary rivets.

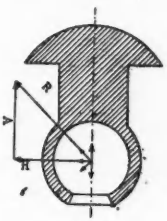


Fig. 6

(3) All types of riveting materials can be employed.

(4) It is a one man operation.

(5) The rivets offer a good resistance against corrosion.

(6) Very suitable for repair work.

(7) Cheap.

FIRST TRAINING OF PARACHUTE TROOPS

Condensed from several articles published in *Letectví*, Prague, Vol. XVII.

PARACHUTE Troops are nowadays a recognised formation in every efficient army. Over 1,200 men carried for several hundred kilometres equipped with 150 machine guns and 20 light field guns are routine exercises. These men must be trained "jumpers." It is expected that they should go into action immediately after landing.

One method of training, developed by James H. Strong, engineer of the American Armament Corporation, made use of a tower with a height of about 76 m. Fig. 1 shows the first stage of training with an "ever-open" parachute. The pupil and parachute being lifted by a wire rope (the lifting device stationed within the tower), and dropped with the speed of free fall. Later stages provide free jumps, as shown in Fig. 2, where the parachute is released from the iron ring which keeps it open.

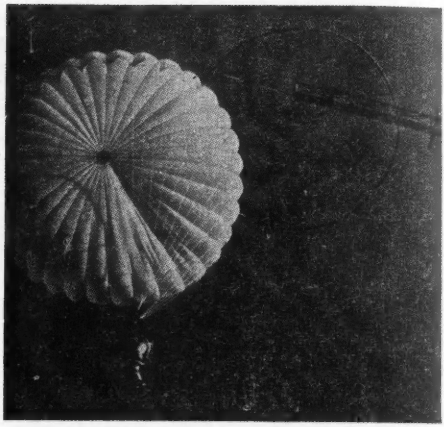


Fig. 2

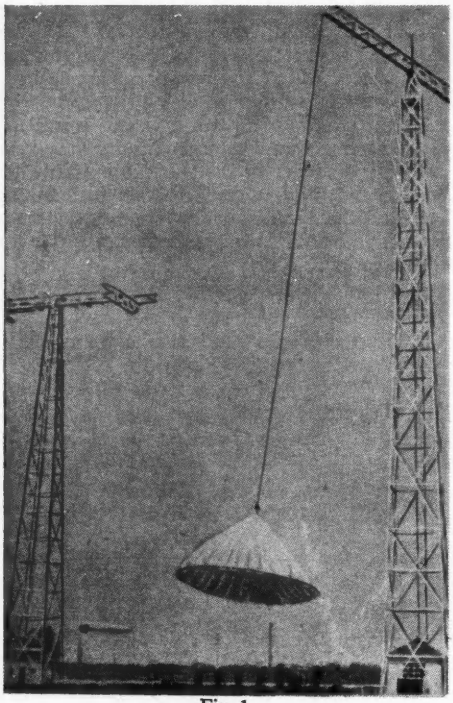


Fig. 1

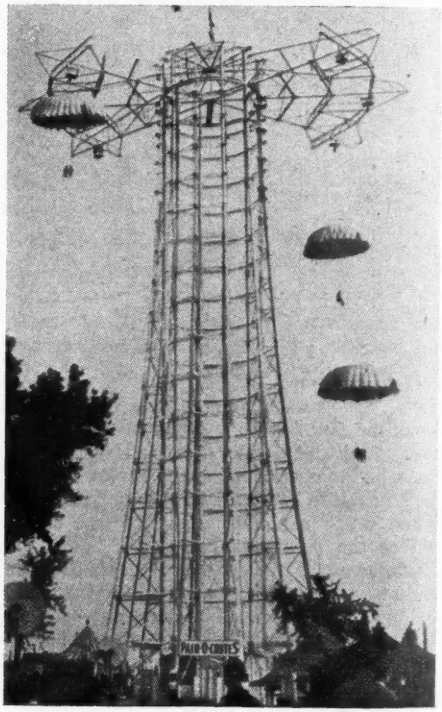


Fig. 3

The final stage comprises free jumps with folded parachute to be opened by the jumper himself as in an actual descent. American business men are understood to use this device for recreation. Fig. 3 shows the tower of an entertainment park in Chicago. Fig. 4 shows the Parachute Tower of Prague, built entirely in the same way as the tubular scaffolds to be seen on buildings under erection or repair in London streets. A wholly different method, described as a Parachute Catapult, was exhibited by the Russians in the form of a model some years ago at the Paris Aerosalon. The Czech firm CKD (Kolben-Danek) has built such a catapult, and this will be the subject of the description given below.*

A six-bladed fan of 3.9 m. diameter driven at 600 r.p.m. by an electric motor of 150 KW. provides the airstream necessary for lifting the parachute. Fig. 5 illustrates how the parachute, which was laid beforehand on the grate

*Since the German invasion of Prague it is unknown whether this method has been adopted. *Editor.*

Fig. 4

Fig. 5

Fig. 6

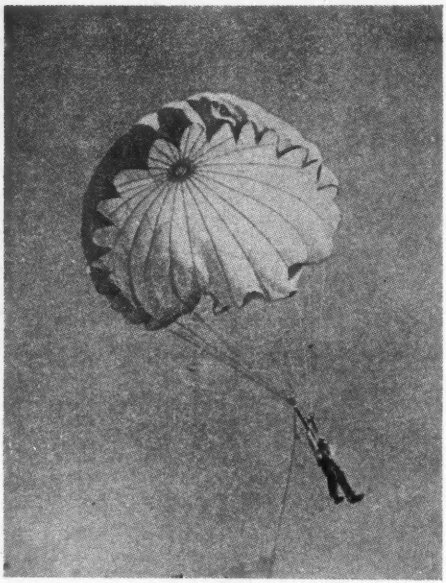


Fig. 7

forming the cover of the catapult, is about to be inflated by the blast and lifted. The next stage shows the pupil just before "starting" (Fig. 6). Fig. 7 (actual photo 60 m. high

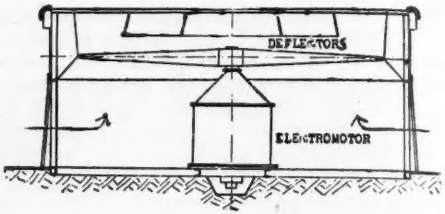


Fig. 8

above the catapult), gives an idea of the parachute used: Area 90 m.², diameter of hole in its centre 0.5 m., velocity of descent 3.5 m./sec.

Fig. 8 shows the general arrangement of the catapult, the arrowheads marking the air entrance to the fan.

Two measurements of the airspeed of the lifting air stream were made (Fig. 9). First, the distribution of airspeed in two perpendicular plans, a and b, as shown in the figure (diagram 1), immediately above the grate; at a height of 1.6 m. above the grate (diagram 2). The difference between curves a and b is caused by the grate interference. The mean airspeed v_s was 12.7 m./sec. This is determined from curve S in Fig. 10 (the airspeed distribution over the catapult radius R is shown, S being the curve of average speed between curves a and b).

A simple calculation gives the efficiency of the catapult:

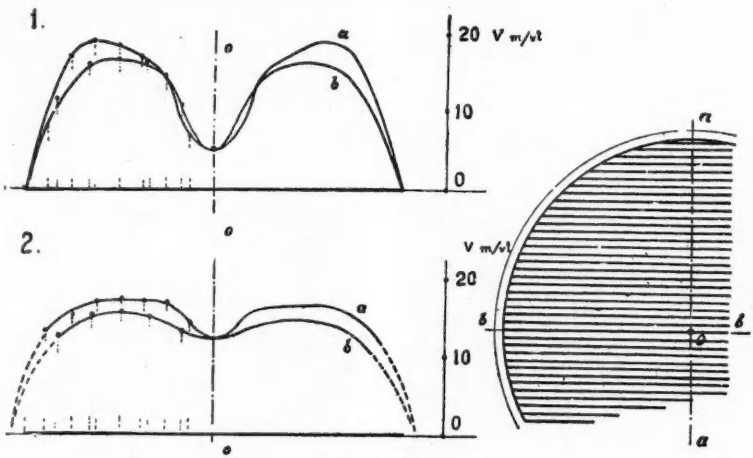


Fig. 9

Let E=energy output of catapult:

$$E = \frac{m\,v_s^2}{2} = \frac{\gamma}{2g} \cdot \frac{\pi D^2}{4} v_s^3$$

or in Horsepower

$$N = \frac{\gamma}{2g \cdot 75} \cdot \frac{\pi D^2}{4} \cdot v_s^3 = 0.000655 \cdot D^2 \cdot v_s^3$$

m=quantity of air m.³/sec.
v_s=mean airspeed m./sec.
γ=specific gravity of air gr./cm.³
g=accleration due to gravity.
D=diameter of catapult in m.
Substituting for v_s:

N=0.000655. 4.1². 12.7³=22.6 HP.

For the motor, output KW.:

$$KW = 1.11 \left(\frac{n}{100}\right)^3$$

for starting of motor n = 320 r.p.m.
KW = 1.11 . 3.2³ = 36 = 48.7 HP.

Efficiency $\eta_i = \frac{22.6}{48.7} = 0.465$.

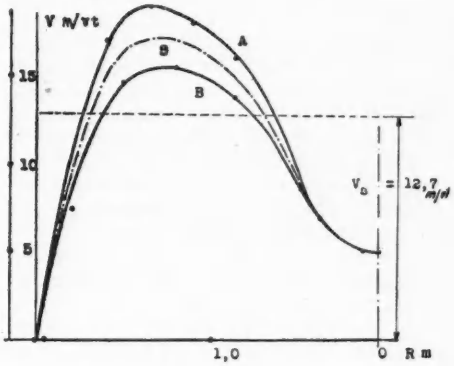


Fig. 10

THE THERMO-PUMP HEATING PLANT OF THE RENOVATED TOWN HALL AT ZURICH

By MAX EGLI, Zürich. (From *Schweizerische Bauzeitung*, Vol. 116, Nos. 6 and 7, August, 1940, pp. 59-64 and pp. 73-75).*

IN the Town Hall at Zürich a heating plant with a thermo-pump was installed in 1938, the first plant with this type of machine and heating system, utilising caloric energy taken from the water of a river. Of course, the temperature of a river—in the plant dealt with in the publication the Limmat flowing through Zürich—is much lower than the temperature of the water circulating through the radiators of the heating plant. But it is possible to utilise the caloric energy contained in the water of the river by the procedure used in ordinary refrigerators, which work with a compressor and a liquid with very low boiling point. It is cooled by vaporizing the Freon liquid, is sent back to the river. The Freon-vapour which contains now the heat Q_1 gained from the river, is then compressed. The energy consumed by the compressor (L) is transformed into heat (A_L) and raises the temperature of the vapour, so that it becomes higher than the temperature of the water circulating in the heating system. The heat energy (Q_2) of the vapour originating partly from the water of the river and partly from the energy driving the motor of the compressor ($Q_2 = Q_1 + A_L$), is used in this way to warm the water of the heating system. In giving up its heat content, the vapour is cooled and condensed to the liquid, with which the process has been started, but having now a high pressure (about 15 kg./cm.²). It expands through a reducing valve to the original pressure and temperature, and re-enters the cyclic process. With 1 kWh of electric energy, used to drive the motor of the compressor, equivalent to 860 kCal, a quantity of about 2,000 kCal gained from the river may be made useful in a plant like that in the Town Hall at Zürich.

*For complete information about the thermo-pump system see previous publications: *Schweizer Archiv*, 1938, No. 11, and *Schweizer Bauzeitung*, Vol. 114, 1939, No. 1, p. 11. In a previous publication of the author, dealing with the same object (*Bulletin de L'Association Suisse des Electriciens* [ASE], Vol. 29, No. 11, 1938, May 25th), the principle of the system is described as follows: The passage of heat from one body, for instance the water of a river, to another body of higher temperature as the water circulating in the heating system, is impossible, if there is no supply of additional energy from outside. This energy (L) is transformed into heat within the compressor of the thermo-pump, and is used together with the heat energy gained out of the water of the river (Q_1) to heat the water of the central heating system. The water of the river—in the case of the Limmat with a temperature between 3° and 15° C.—is used to vaporise a liquid, for instance, dichlordifluormethane (commercial designation Freon 12), which boils at a very low temperature (Freon boils at 7° C and at an absolute pressure of 2.5 kg./cm.²). The water of the river after it is

essential for this process—bringing caloric energy from a body at low temperature into another body at a higher temperature—to put mechanic energy into the process by driving a compressor. Only a very small fraction of this energy gets lost in covering the inevitable working losses of the motor and the compressor, the overwhelming part is converted into heat, which, added to the caloric energy taken from the river, is utilised in the heating plant.

The publication deals in detail with the manner in which the new ventilation plant, which had to be installed together with the new heating plant in the Zürich Town Hall, had been arranged in order to avoid deterioration of the very beautiful, antique panel work of the old and famous building.

A calculation and a diagram based on the temperature of the water of the Limmat during the year, and on the quantity of heat energy necessary to heat the rooms of the Town Hall to a temperature of 18° C., showed that a thermo-pump working under the conditions prevailing at Zürich could deliver 1,860 kCal for each kWh of electric energy consumed by the motor driving the compressor. In regard of the better efficiency of a thermo-pump plant (90%) in comparison with a plant using oil as fuel (70%), these 1,860 kCal are equivalent to 2,390 kCal when fixing the price which can be paid for 1 kWh consumed by the thermo-pump, based on the cost of 1 kCal, when produced in an oil fuel plant.

Fig. 1 shows the machinery of the plant. The publication contains detailed figures of the compressor (1 in Fig. 1), the evaporator (3), the condenser (2), and the hot water accumulator, which is combined with the thermo-pump in

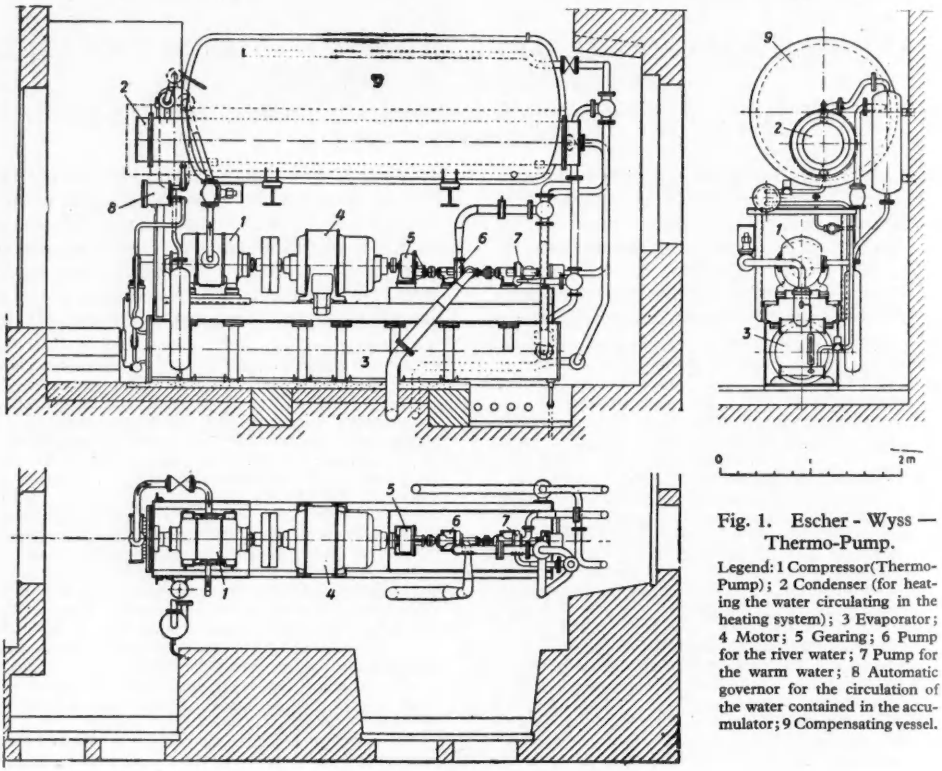


Fig. 1. Escher - Wyss — Thermo-Pump.

Legend: 1 Compressor (Thermo-Pump); 2 Condenser (for heating the water circulating in the heating system); 3 Evaporator; 4 Motor; 5 Gearing; 6 Pump for the river water; 7 Pump for the warm water; 8 Automatic governor for the circulation of the water contained in the accumulator; 9 Compensating vessel.

order to cover the great peaks of heating energy, which are necessary on days when the great halls of the building are used for meetings. This accumulator, heated during the hours when surplus energy is available, can store 600,000 kCal, which may be used at a rate of 150,000 kCal per hour. The amount of additional circulation of water contained in the heat accumulator is governed automatically by a thermostat.

After the first heating period an acceptance test was made. The results of some measurements are contained in Table I, which gives a good insight in the working of the plant. The test proved that the guarantees were fulfilled.

TABLE I.
RESULT OF THE ACCEPTANCE TEST.

Circulation of the water of the Limmat.

Inlet temperature tL_1 °C.				
9.3	9.4	9.5	9.8	9.8
Outlet temperature tL_2 °C.				
7.65	7.1	6.5	6.55	6.84
Quantity of water W_L m³/h.				
22.1	22.38	22.38	14.09	12.0
Quantity of heat Q_1 kal/h.				
36,600	51,000	66,300	46,000	(36,500)

Circulation of the water in the Condenser.

Inlet temperature tK_1 °C.				
52.74	42.32	30.22	33.9	33.2
Outlet temperature tK_2 °C.				
57.47	47.7	36.58	38.8	37.8
Quantity of water W_K m³/h.				
15.8	15.95	15.85	15.88	16.2
Quantity of heat Q_K kal/h.				
74,700	85,700	100,200	77,500	74,500

Circulation of the water in the heating system.

Inlet temperature tH_1 °C.				
51.7	39.62	29.5	32.28	32.22
Outlet temperature tH_2 °C.				
57.17	48.06	36.76	38.55	38.23
Quantity of water W_H m³/h.				
13.32	10.0	14.62	11.8	11.9
Quantity of heat Q_H kal/h.				
72,400	84,400	106,000	74,000	71,500

Circulation of the Freon liquid.

Pressure in evaporator p_V at abs. press.				
2.65	2.49	2.21	2.0	1.815
Temperature in the evaporator t_V °C.				
3.0	1.61	0.5	—3.2	—5.0
Pressure in the condenser p_K at abs. press.				
15.70	12.73	10.0	10.19	9.9
Temperature in the condenser t_K °C.				
102.5	84.6	76	60	56.3
Energy input L W_K.				
47.67	42.78	36.96	36.11	34.99
Equivalent heat energy A_L kal/h.				
36,500	32,900	28,500	27,800	27,000
Relation of gained heat to energy input $\frac{Q_K}{L}$ $\frac{\text{kal}}{\text{kWh}}$				
1570	2000	2720	2145	2130
Relation of heat delivered into circulating warm water to input of electric energy.				
$\frac{Q_K}{A_L}$ 1.81	2.32	3.16	2.49	2.47

During the heating period, 1938/39, a continuous survey of the working of the plant was made by a set of automatic measuring instruments. This extensive examination showed that the calculations made when projecting the plant were right, especially the relation of 1,830 kCal for 1 kWh at normal working conditions.

In order to illustrate the importance of this practical trial of the new system, it is emphasised that Switzerland has to pay yearly 100 million Swiss francs for imported fuel for room heating equivalent to 15.10^9 kWh, and that the increase in the price of coal imported to Switzerland during the Great War amounted to 1,000 million Swiss francs. The advantages of the system are so great that it is expected that the investment cost will not prevent extensive use of the system. The cost of the first model plant in Zürich cannot give indication of lower cost, which will be attained when more plants are built.

A GAP IN THE PROTECTION OF BUILDINGS AGAINST LIGHTNING: PROTECTION AGAINST ENDANGERING BY LIGHTNING OWING TO OVERHEAD NETWORK

By DR. A. ROTH, Manager of Sprecher & Schuh A.G., Aarau. (From *Schweizerische Bauzeitung*, Vol. 116, No. 7, August, 1940, pp. 71-73, 5 Figures).

THERE is no question about the usefulness of lightning conductors for buildings, which, by their situation, are liable to be struck by lightning. A recent publication by Ch. Morel* dealing with the result of the statistics collected in Switzerland from 1925 to 1937 is a valuable

document proving this view. The damage caused by lightning during 1925-1937 to buildings covered by these statistics and not protected against lightning, insured for 280 million francs, amounts to 5 million francs, whereas the damage to buildings with lightning protection, having an insured value of 140 million francs did not exceed 500,000 francs. Half of this sum concerns buildings with imperfect lightning conductor installation. The average amount of individual damage was 900 francs with the protected and 1,400 francs with the unprotected buildings.

The statistics mentioned before give evidence that the endangerment of buildings is intensified by electric plants, if the overhead lines are not properly equipped with lightning arresters. Out of 5,828 cases of damage which were reported, caused by lightning on buildings without lightning conductors, 2,901, i.e. half of them, were caused by surges, which originated from the overhead lines, the building itself not being struck by lightning. The same proportion has been stated with buildings equipped with a lightning conductor, as 634 out of a total of 1,220 cases of damage originated from sparkovers caused by excess voltages due to lightning surges in the electric plant. The average amount of the damage in these cases of "indirect lightning" was only 200 francs against 1,500 francs as average damage, when the building itself was struck.

These figures show that in buildings with electric installations supplied from overhead lines, only half of the cases of damage by lightning can be prevented by lightning conductors. For avoiding the rest, special precautionary measures in the electric light installation have to be arranged.

There are two kinds of surges: Surges caused by a direct lightning stroke into the line and voltages caused by sudden changes of the electric field between the clouds and the earth, occurring when the clouds are discharged by strokes between the clouds, or between the clouds and the earth; Indirect strokes. In the latter case neither the building nor the electric line are hit directly. But the high voltages, which may be induced in the overhead lines, may cause flashover or puncture of the insulation of the indoor system. As the energy of such surges will be rather small, the discharge current will not exceed a few hundred amperes and will not last longer than a few μs. Therefore, these discharges will not cause direct damage to the building, if the spark does not occur in a room filled with explosive gases or other similar materials. But, of course, they are dangerous to living creatures.

By far more dangerous are direct flashes striking the overhead lines. They may have some 100 up to 100,000 amperes and may last up to 200 μs. By the great charges the lines may be brought up to several million volts. The insulation of the indoor system connected to the overhead lines cannot withstand such surges, and great damages or fires may be caused owing to the great energy involved in flashovers or ruptures of insulation.

All excess voltages in the indoor installation can be eliminated by installing a lightning arrester to the low-voltage circuit, comprising an air-gap and an arrangement to stop the current following the arc over the gap. A gap of 0.25 mm. will arc over at a voltage of 1,200 $\sqrt{2}$ volt, i.e. below the electric strength of the installation. In order to avoid dangerous voltages in the installation due to the drop of the current flowing to the earth, it is necessary to secure a very low resistance of the earthing lead of the arrester.

All lightning arresters employ gaps in air of atmospheric pressure, but they differ in regard to the extinction of the arc. Figs. 1 and 2 show a widely used arrester with an electromagnetic extinction. The gap is formed by the electrode (3) of hemispherical shape, which is connected with the circuit to be protected, and by the plate (4) connected to earth over a blow out coil (5). This coil produces a magnetic field between the plates (1 and 4). The lines of force having a radial direction make the arc started between 3 and 4 rotate round the axis of the arrester with a very great velocity (about 100 m/s). The contact with the cold air cools the arc, so that it extinguishes with the next current zero, i.e. within 0.01 s. Although the blow out coil consists of only a few turns, its inductivity may behave as appreciable inductive resistance in case of heavy and quickly rising lightning currents. Therefore,

*Secretary General of SEV and VSE (Ch. Morel): Lightning Strokes and the Protection of Buildings against Lightning. Statistical research on the lightning strokes on buildings in Switzerland from 1925 to 1937, *Bulletin SEV*, Vol. 31, 1940, p. 178.

the coil is shunted by another air gap (8-9), which sparks over in such cases, but extinguishes immediately the quick change of the lightning current ends.

The arrester starts at 1,200 $\sqrt{2}$ V. It has been successfully tested up to 12,000 A.

Other types of arresters extinguish the current started over the gap by resistances in series with the gap, the resistivity of which decreases the more the higher the voltage across the resistance. In case of surges these arresters are able to pass very heavy currents to earth, whereas no current flows at normal voltage.

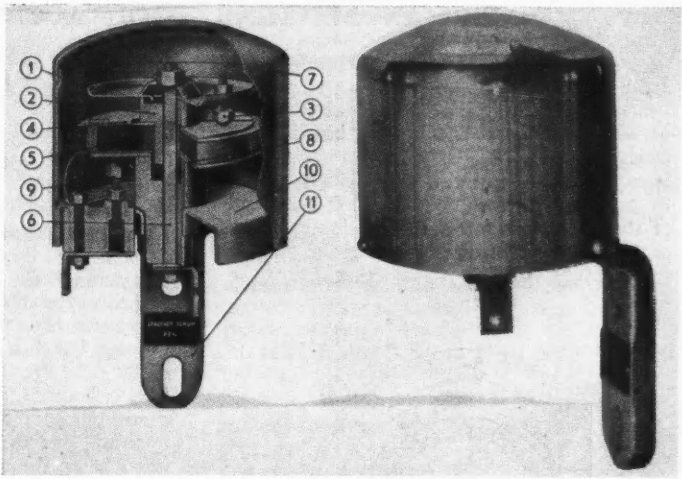


Fig. 1. Lightning arrester with electro-magnetic arc extinction 380 and 500 V (Sprecher & Schuh). Legend in the text.

The author recommends the observance of the following points, when installing lightning arresters for indoor installations:

(1) Each phase not earthed inside the building should be provided with an arrester.

(2) The arresters may be connected before or behind the main fuses. (The author recommends the latter arrangement, in order to have an arrester cut out, should it become defective).

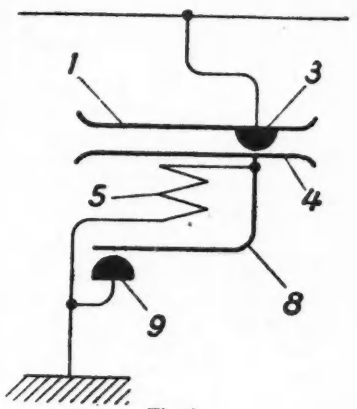


Fig. 2
Diagram of connections of arrester (Fig. 1)

(3) The earthing lead should be insulated (4,000 $\sqrt{2}$ V.) down to the earth; cross section 16 mm.^{2} (0.025 sq. in.), buried in the ground as far as 25 mm.^{2} (0.039 sq. in.). The lead from the arrester to the ground has to be made as short as possible.

(4) Earths of the lightning conductor, of the lightning arresters for the heavy current, and for the telephone and of the radio protective earthing have to be connected. For new installations it is best to provide a good common earth. It should have low resistance or embrace the whole area of the building (ring electrode, if necessary with cross connections) in order to avoid potential differences within the building. It is recommended that the water pipe be used for earthing, or if an earth plate is provided, it should be connected with the pipe, which has to be free of electric interruptions for a distance of a few hundred yards.

Though it seems not absolutely necessary to provide arresters for every building in villages, it is strongly recommended to install them in places where strokes had been experienced and in buildings on hills and mountains; furthermore, in detached buildings and in buildings with special danger of fire.

GERMAN MACHINE TOOL ACCESSORIES

(From *Die Werkzeugmaschine*, Vol. 44, No. 2, January, 1940, pp. 29-35)

(*Continued from page* 230)

The right hand end of the bearing (20) carries a disc (21) attached to it, in the hub of which a clamping bolt (22) can be moved by turning a handle (23). The left hand end of the clamping bolt is freely admitted to a central hole in the disc (15), and the stop of the clamping bolt (22) is thus lying against the disc.

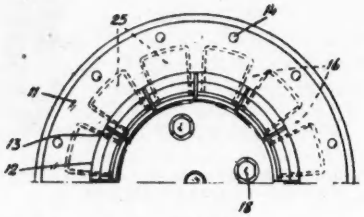


Fig. 4a.

To insert the work piece, the clamping bolt is pressed against the disc and, hence, the jaws open up. After the work piece is introduced in the clamping chuck, the clamping bolt is withdrawn and the jaws grip the work piece. To avoid loosening of the grip, due to centrifugal force, weights (25) are provided, in number corresponding to the number of jaws. The centrifugal action on these weights increases the clamping force at higher speeds.

Device to bend tubes.

Fried. Krupp Germaniawerft Akt.-Ges. DRP. 665.230. This invention is very useful when thick walled pipes have to be bent. The pipe (a) is placed on a strong bearing surface (b) and fixed by the clamps (c and d). (d) is connected to the lever (e). When the lever is turned in the direction indicated by the arrow I, the centre of rotation is (f), and the angle through which it is turned is α. The position of the tube after bending is indicated in dotted lines. Because the centre of rotation and the centre of bending of the pipe are lying on the opposite side of the pipe, a single pressure exists along the cross section of the tube, and all the fibres in the work piece are shortened. The amount of reduction in the length of the fibres depends on their relative position, i.e., the greatest at x_2, and the least at x_1. The neutral axis is always passing through the point (f).

Automatic electric contact governing device.

Machine movements, especially those of slides or saddles of lathes and milling machines, are frequently governed by electric contact governors. For this purpose, a contact lever is employed, which is guided in suitably shaped pattern. It was found that this type of control gives rise to inaccuracies, namely, the movements of the slide or other machine parts do not follow exactly the movements of the contact lever. These deviations are mainly due to the fact that correct machine movement can only be obtained if the contacting movement lies in the same plane as the intermediate lever.

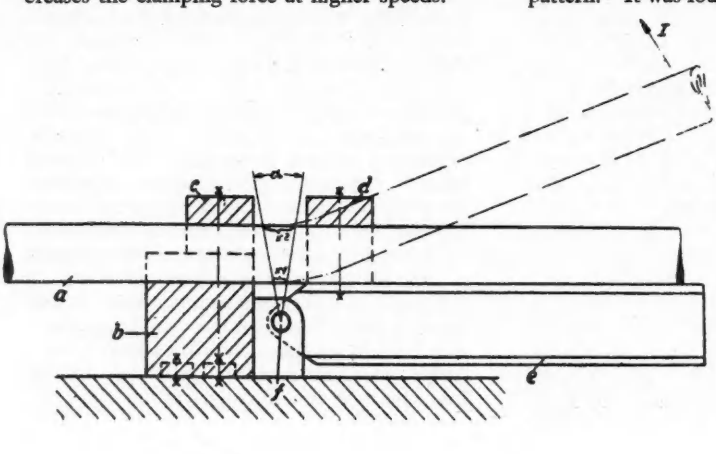


Fig. 5

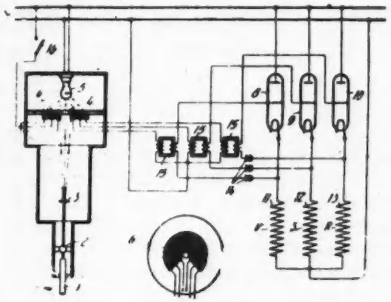


Fig. 6.

The invention DRP. 667.285 Siemens Schuckertwerke Akt. Ges. (inventor Dr. Ing. Wilhelm Lenkert) refers to contact governors with the tracer movable in all directions, and where the amplitude of the tracer determines the direction of the machine movement.

The principle of the invention is to replace the mechanical contact (which is liable to cause disturbances in the electric circuit) by photo-electric control, and also to eliminate the intermediate lever. The tracer acts on the beam of light, which operates the photo-electric cells. A separate photo-electric cell is provided to control each of the three directions of movements. The cells are arranged along a circle, equally spaced from the rest position of the light-ray, which is reflected from a mirror attached to the tracer. A further improvement is obtained if the cells are connected up to the grid-circuit of the discharge valves, which serve as a switch to the electro-magnetically operated couplings.

The tracer (Fig. 6) consists of a bolt (1), which is supported in the sphere (2), and carries a small mirror (3). The mirror reflects and diverts a beam of light, emitted by the bulb (5) and passing through the hole (4). Three photo-electric cells (6) are arranged around the hole (4). The grids of the three discharge valves (8, 9 and 10) receive a negative charge from the accumulator (14). They close the electric circuit to the three windings of the electro-magnetic couplings (11, 12 and 13). Coupling (11) controls the forward movement, coupling (12) controls the sideward movement, and coupling (13) the return movement. The secondary windings of three small transformers (15) are connected up in the grid circuit through which positive charge is admitted to the grids at the instant when the photo-electric cells become conductive to currents. The secondary diagram shows the arrangement of the photo-electric cells around the hole (4).

Device to improve the shaping of the curved surface of toothed grinding discs.

Zahnfabrik Friedrichshafen, Akt. Ges. DRP. 668.068. The patent gives a device to eliminate the continuous deviations of the curved surface of the grinding discs from the pattern of the guiding curve.

The trueing device (Fig. 9a) is placed between the centres (2 and 3) of the grinding machine, in place of the toothed-gear. The device consists of the body (10) on which a support (12) is provided which can be adjusted and fixed in position. The support (12) carries a small ball and socket joint (19). At the other end a similarly adjustable support (14) is provided to carry the involute disc pattern (15).

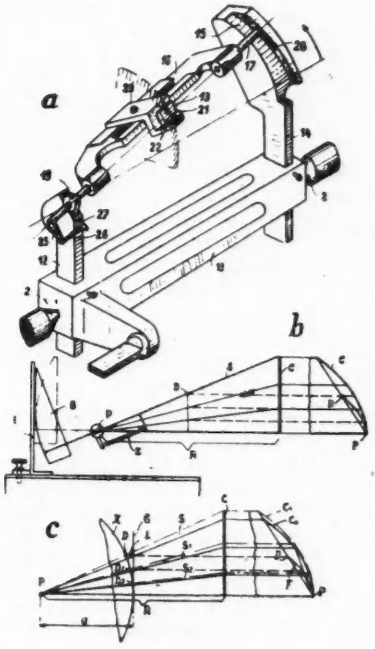


Fig. 7.

A bridge part (18) serves as tool carrier and is guided on the involute disc with its pin shaped end (17). The bridge (18) is provided with guiding grooves and a block (20) is fixed on to it. On the block (20) a toolholder (22) is fixed with a bolt (21). The toolholder carries the trueing tool (13). The point of the tool lies in line with the polar axis of the bridge, passing through (19) and the pin (17). Also, the axis passing through the bottom end of the path of the tool is indicated in Fig. 9a. An arm (25) is attached to the bridge (18), and a spring (26) is pulling the bridge along the polar axis in the direction of the involute disc. The pin (17) is pressing against a rim (28) attached to the involute disc. If the toolholder swings in the direction of the arrow (Fig. 9a), than the point of the tool is describing a path, the plane of which is parallel to the plane of the involute disc, and is indicated by dotted lines on the figure.

In the sketch 9b (P) is the polar axis and (R) the base axis. (C) indicates the guiding curve which is shown in side view on the right hand side of the figure. The axis (S) represents here the tool carrier. The small curve at the right hand side (P-D) represents the curve to be traced by the tool. The axis (S) is extended to the left beyond (P) and carries on its end a spherical calotte (B), which lies against a guiding surface (E) parallel to the guiding surface (C). (E) is adjustable with respect to (P) along the axis (R). A spring (Z) pulls (B) towards the surface (E). Due to the sliding of the polar axis (S) along the surface (C), the tool (D) receives the required displacement along the polar axis, which is necessary to equalise the continuous deviations from the path corresponding to the pattern.

COMBUSTION OF WASTE-WOOD PRODUCTS

By H. W. BEECHER and R. D. WATT. (From *Combustion*, Vol. 12, No. 3, September, 1940, pp. 35-38).

THE waste products resulting from the production of lumber, plywood or cellulose for conversion into pulp are available as fuel. Manifestly, any portion of the log which can be economically converted into more valuable material should neither be classified as waste wood, nor used for fuel. Sawdust and shavings can be handled for burning without further processing. Slabs, edgings, trimmings and other waste products require further size reduction to prepare them for rapid combustion. Such material is usually processed by a mechanical masticator, commonly known as "hog," and the product is known as "hog fuel."

Economic aspects.

Mill production cost for the hogged portion of fuel is from 10 cents to 15 cents per unit. The large volume and weight of hog per fuel available BTU. makes the transportation cost loom large in the total cost to the consumer. The economical marketing zone is limited by transportation costs.

The high moisture content of hog fuel materially reduces the obtainable thermal efficiencies of boiler plants, as compared with the efficiencies secured with other fuels. This necessitates comparison of hog fuel with other fuels on the basis of their relative costs per available BTU. Many consumers of hog fuel pay as little as 50 cents a unit delivered. In other plants the hog fuel cost reaches $3.50 per unit. A unit of hog fuel measurement occupies approximately 200 cu. ft. An average unit of hog fuel will contain about 20,000,000 BTU. Boiler plant efficiencies with hog fuel vary, depending upon the type of installation and are of the order of 45-65 per cent.

To indicate the general low cost of hog fuel, it may be noted that assuming 60% efficiency, the available heat per average unit would be 12,000,000 BTU. At a cost of $1 the corresponding cost of steam production would be 8⅓ cents per million BTU. input. With fuel oil, the cost would be 19 cents per million BTU. input and with coal the cost would be 20 cents per million BTU. input.

Availability of Waste-Wood Fuel.

An analysis of a total volume of 1,354,000,000 cu. ft. of wood, showed that of the solid wood material, inclusive of bark, represented by the logs as delivered to the sawmill, 41% is so-called "waste" and available for fuel. It is reason-

able to assume that the material left in the forest, such as tops and branches, is sufficient to make up the difference between 41% and 50%. Although there might be some slight improvement in utilisation, nevertheless as long as sawmills are operating at reasonable capacities, log fuel in abundance will be available for industrial use.

Heating value.

The high percentage of oxygen in wood reduces the heat content per pound as it is combined with carbon and hydrogen to form carbo-hydrates and, therefore, the total heat of combination of the combustibles is not all available. Hog fuel as normally delivered contains a high percentage of moisture. The hog fuel used in industrial plants of the North-west will average from 25% moisture, when principally kiln-dried material, to from 57% to 60% of moisture, when largely green hemlock.

The heating values of stored hog fuel varies with the time in storage. Storage of hog fuel in open decreases the available BTU. faster than storage under cover. This loss of heating value is attributed to slow oxidation which takes place at low temperatures. A typical ultimate analysis of wood is as follows :

Carbon	..	50.31%
Hydrogen	..	6.20%
Oxygen	..	43.08%
Nitrogen	..	0.04%
Ash ..	..	0.37%

Combustion of Hog Fuel.

Nearly 45% of the dry weight of wood, independent of the species, is oxygen. The hydrogen to carbon ratio in wood is of the same order as in oil and, therefore, for the same excess of air, the percentage of water vapour as compared to dry gases will be approximately the same for these fuels. The heating value of the fixed carbon in wood fuel amounts to from 15% to 20% of the total heat in the fuel. The high moisture and volatile contents of hog fuel delay combustion which proceeds as follows :

(1) The driving off of the moisture content and raising the wood to a temperature at which volatiles will be driven off.

(2) The actual distillation of volatiles.

(3) The combustion of fixed carbon.

The high oxygen content of wood with its low nitrogen content reduces the percentage of nitrogen in hog fuel flue gas. Wood of the typical analysis quoted will give, if completely burned without excess air aprpoximately 20% CO_2. With deep fuel beds, most of the fixed carbon leaves the fuel bed as CO, where it unites with additional oxygen to burn to CO_2.

In the cellular type of furnace, it is important to provide secondary or overdraft air. The standard method to feed fuel to flat-grate cellular-type furnaces is through feed-hole openings located in the furnace roof, the fuel being transported to the furnace through chutes. Reasonable precautions are necessary to limit the amount of air entering the furnace through these chutes.

Design of Furnace.

The furnaces must be suitably designed to deal with fuels varying in size from dust to pieces having 3 to 5 cu. in. of content and for fuels for variable moisture content. The designer must provide furnaces to handle properly the wet fuel, and at the same time, not to punish unduly refractories during the periods in which only dry fuel is fed. Much study has been given to the use of sloping-grate furnaces, where the fuel is admitted in a comparatively thin layer over a drying hearth, in which portion of the furnace reflected heat is utilised to drive off the moisture. Practical difficulties are encountered with sloping-grate furnaces caused by the fuel not being uniform in size, and not being of uniform moisture content. Both these lead to formation of blowholes through the fuel. After the moisture and volatiles have been driven off, leaving charcoal cinders, these blowholes lift the cinders from the grate, depositing them at the foot of the sloping section, and, in their formation prevent the fuel from above the blowhole cascading to cover the hole. The accumulated charcoal cinders afford such high resistance to the passage of air that insufficient air passes through this material. This prevents the combustion at the toe of the grate proceeding with sufficient rapidity to obtain high ratings per square foot of grate area.

Hence, the necessity of using conical-pile furnaces with which by far the greater number of hog fuel fired boilers are equipped.

An advantage of the cellular type of furnace is the ability to operate a boiler at reduced rating while burning down and cleaning of slag from the grates in one of the multiple cells.

In comparable installations, the gas weights with hog fuel are approximately 1.7 times the gas weights with oil, and approximately 1.25 times the gas weights with coal. This increased gas weight results in lower combustion-chamber temperature which is further reduced by the high moisture content of the hog fuel gases. These factors make it essential to provide larger combustion spaces with hog fuel than with other fuels.

Use of Preheated Air.

With the modern boiler installation the increased capacity obtainable with preheated air has been largely responsible for the installation of preheaters, rather than any gain in efficiency resulting from their use. With hog-fuel, it is impossible to obtain, as low exit-gas temperatures, in part result from the fact that only 75-80% of the air required for combustion can be passed through the air preheater. The use of preheaters has made it necessary to use water-cooled grates to avoid excessive grate maintenance. Water-cooled grates have also proved desirable to facilitate grate cleaning.

In many installations, the heat obtained in grate-cooling water is used to heat, condensate or makeup water. The heat absorbed in the cooling water is low-potential heat and must be substructed from the heat available for the production of steam. It is important to provide an arrangement for cooling, which will extend the life of the grate, provide easy cleaning, and, at the same time, extract from the grates and from the preheated air passing through them, a minimum amount of this low-potential heat.

Driers.

Hog fuel driers offer attractive potential saving to the power-plant operator. The flue gas leaving an air-heater at approximately 500° F., contains sufficient heat to remove about ½ lb. of water per lb. of dry wood. In addition to the savings, the drying of hog fuel gives considerably increased capacity per square ft. of grate. Several different types of hog fuel driers have been proposed and tried, but the authors do not know of any design which has proved completely satisfactory.

Cinder Nuisances.

The cinder nuisances from hog fuel burning has increased with higher firing rates required with the modern high duty boilers equipped with forced and induced graft fans and air preheaters. Modern hog fuel burning plants are providing either mechanical separators or flue-gas washers for cinder removal.

Boiler Capacities.

Tandem furnaces do not operate as well as those with a single feed hole per cell. Any boiler should have a minimum of 2 cells to permit carrying partial load during grate cleaning periods. The following table is intended to indicate in a general way what capacity should be expected from a well designed furnace cell of the general dimensions used in modern installations.

	BTU. per sq. ft. of grate area.	
Moisture in fuel	Without preheater	With preheater
40%	680,000	850,000
48%	550,000	690,000
56%	400,000	500,000

The above figures reflect what can be accomplished under good conditions in properly designed furnaces.

MOLYBDENUM IN IRON AND STEEL

By THERON D. PARKER. (From *Mechanical Engineering*, Vol. 62, No. 11, November, 1940, pp. 793-799).

MOLYBDENUM is one of the newer metals to gain importance as an alloying element. Recent developments have led to the use of molybdic oxide either in powder form or in the form of briquettes. Both canned oxide and briquettes are used for making molybdenum additions to the cupola, electric, open-hearth, or air furnaces. The use of calcium molybdate is confined to the electric, open-hearth and air-furnace melting practice, where the additions can be made either with a charge or shortly after the meltdown. Ferromolybdenum of suitable size is regularly used for both furnace and ladle additions. The benefits resulting from the addition of molybdenum to cast iron are primarily due to its solid solution and mild carbide-

forming characteristics. It also breaks up the graphitic structure and tends to produce a shorter curled flake. Molybdenum will give improved physical properties in almost all classes of iron without changing from the regular furnace charge and melting practice. Generally it increases the tensile strength of cast iron, increases the modulus of elasticity of the iron, pronounced improvement in the wear resistance.

Molybdenum Steels.

The versatility and comparatively low cost of the chromium-molybdenum steels have caused them to become a most popular type. The frequent application of molybdenum led to the present S.A.E. specifications. Altogether thirteen different molybdenum-containing steels are standardised. The S.A.E. X4130 is well-known for its good weldability in light sections and high weight-strength ratio. The higher carbon steels S.A.E. 4140 and 4150 are widely specified for gears, pinion shafts, drive shafts, tools, etc., in the machine tool and automotive industries.

While the low-carbon carburizing type of chromium-molybdenum steel is not listed among the S.A.E. specifications, it is being applied as a low-cost steel in a number of cases where the fine properties of the S.A.E. 4600 carburizing steels are not necessarily required.

Nickel-molybdenum steels are well-known for their low distortion characteristics during carburizing and oil hardening treatments. The low carbon types are extensively used for carburized parts where a hard, tough, and wear-resistant case is desired. This type of steel can be quenched directly from the carburizing temperature and maintain a fine grain structure which is necessary in both the case and core if the maximum serviceability is to be obtained.

Nickel-chromium-molybdenum steels of the S.A.E. 4300 type are primarily designed for heavy sections and highly stressed parts. These steels respond to both air-cooling and oil-quenching treatments, and develop good ductility and toughness combined with a high yield-tensile ratio.

High-Temperature Steels.

High-temperature steels and molybdenum have become kindred subjects wherever elevated temperatures are encountered. This is due largely to the pronounced increase in creep strength which accompanies the addition of molybdenum. Space does not permit a discussion of the various analyses that are produced, but an idea of the range of creep strength and oxydation resistance of several steels can be obtained from Table I.

TABLE I.

	Creep strengh 0.01%/1000 hr.			Relative Oxidation
Composition . .	1000 F.	1100 F.	1200 F.	1200 F.
Carbon	2150	—	—	100
Carbon 0.50% Mo. . .	5200	—	—	115
2.00% Cr. 0.50% Mo.	6300	3325	1100	50
3.00% Cr. 0.90% Mo.	7000	4200	—	35
5.00% Cr. 0.50% Mo.	7200	2400	900	25
9.00% Cr. 1.15% Mo.	8500	3775	1600	11

By a careful selection of the chromium, silicon and molybdenum contents, an analysis can be developed to meet a wide variety of operating conditions.

The improvement in physical properties at temperatures above 650 F. resulting from the addition of 0.40 to 0.60% molybdenum makes it possible to use these steels at higher temperatures than carbon steel. This may result in improved efficiency of the equipment.

High-Speed Steel.

It was found that, at least within limits, tungsten can be replaced by molybdenum on the basis of about one part of molybdenum for each two parts of tungsten. These steels are successfully competing with tungsten steels on a performance basis. The steels generally contain from 8.00-9.50% molybdenum, 1.25-2.00% tungsten with the usual 4% chromium and 1% vanadium. As in case of tungsten steel, the hardening temperature for molybdenum high-speed steels will vary with the analysis and the type of tool. In general, however, the proper hardening temperature is lower for the molybdenum steels. Molybdenum steels have a greater tendency to decarbonize than tungsten steels. It is, therefore, more necessary to protect the surface of these steels during forging, rolling, and heat-treating operations. A more recent type of molybdenum high-speed steel, containing 4.00-6.50% molybdenum and a like amount of tungsten, has an advantage in that it is not subject to decarbonisation during fabrication and heat-treatment to as great an extent as the steels previously mentioned. The addition of about 2.5% of copper

practically eliminates the remaining tendency of the steel to decarbonize. The lower cost of the molybdenum steels, combined with the fact that, owing to the lower density, from 7 to 10% more tools can be produced from the same weight steel, has caused a rapid growth in the use of molybdenum steels for cutting tools.

Molybdenum in High-Chromium and Chromium-Nickel Alloys.

In the family of high-chromium steels, those containing 12% or more chromium—there are a number of types containing 0.50% or more molybdenum. It has been observed that the presence of this element assists in refining the grain and improving the machineability of these steels. It also improves the impact properties, and under certain conditions, enhances the corrosion resistance.

Effect of Molybdenum in Pearlitic Steels.

Structurally, the effect of molybdenum appears to be one of gain, refinement and restraint of austenite grain growth. Molybdenum steels can be heated to higher temperatures with reduced danger of grain growth. Absence of the abrasive scale promotes longer die life. It has been noted that molybdenum steels flow well under the hammer. However, the retention of strength of molybdenum steels at high temperatures results in increased stiffness. It does not greatly affect the maximum hardness obtained by quenching, but it does have a pronounced beneficial effect on the hardenability.

Molybdenum steels generally require a higher drawing temperature after hardening than unalloyed and alloyed steels not containing this element. Temper brittleness is practically eliminated by the addition of molybdenum. This makes the element particularly advantageous in steels used for heavy sections where it is inconvenient to resort to the use of liquid quenching from the drawing temperature.

Hardness Penetration as Affected by Molybdenum.

A fundamental approach to this subject can be made by studying the temperature *vs.* isothermal-reaction-rate curves, sometimes called "S-curves," for carbon and alloy steels. In what follows we shall concern ourselves primarily with the effect of carbon and molybdenum on the position and form of the reaction-rate curve, and by so doing, attempt to illustrate another important function of molybdenum in steel, namely, its effect on hardness penetration.

There are two significant portions of the temperature *vs.* isothermal-reaction-rate curve that will be considered. The first is that portion of the curve lying between the constant temperature lines of about 900-1,100° F., and often referred to as the nose of the curve. It is within this range that rapid decomposition of austenite occurs. The position of this portion of the curve in relation to time largely governs the hardenability of steel. If the time for initiation of austenite decomposition within this temperature range is short, it follows that the steel is shallow hardening since it would be impossible to cool a sizable section rapidly enough to prevent austenite decomposition.

The second significant portion of the curve lies between the constant temperature lines of 900° F. down to some 3-400° F. The decomposition products formed within this range are harder than those formed at the higher temperatures. In general, the hardness increases as the temperature of isothermal transformation decreases. In order that a steel may have deep-hardening characteristics and still develop acidular products which possess a relatively high degree of ductility, two conditions must be present:

(1) The nose of the curve must be far enough to the right to permit the steel to be cooled in the section desired through this temperature range with a minimum of austenite decomposition.

(2) The reaction-rate within the temperature range of about 900-400° F. must be sufficiently rapid to allow transformation to go to completion before the steel is cooled to a temperature below about 400° F.

Fig. 1 shows that the position of the reaction-rate curve may be altered by varying the carbon content of a steel. Two sets of curves are shown, those on the left represent the time required for the beginning of the pearlite reaction in isothermally treated specimens of the three steels tested, while those on the right represent the time required for complete decomposition of the austenite. The curves show that decreasing the carbon content below that

of the eutectoid composition causes the nose of the curve to be displaced to the left. Low carbon contents also restrict the austenitic area in the temperature range of 800 to 300° F. Carbon content in excess of the eutectoid composition caused the nose of the curve to be displaced to the left, while concurrently, the time required for initiation of transformation at 600 to 400° F. is greatly increased. If the steel is cooled in excess of its critical quenching rate the austenite will remain stable down to lower temperature, and the final products of decomposition will be harder.

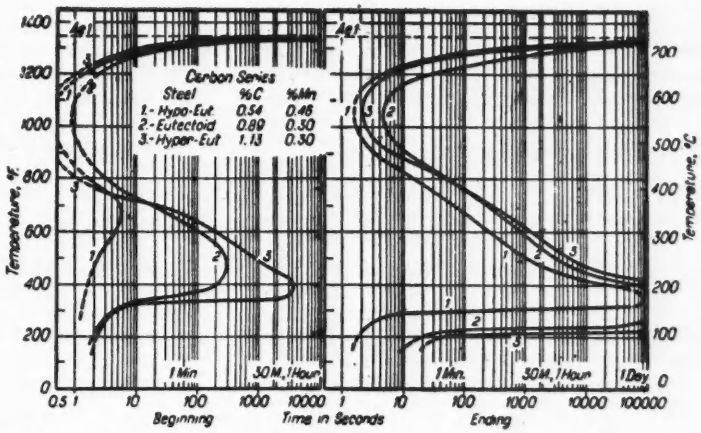


Fig. 1.

Influence of Carbon on the Isothermal-Reaction-Rate Curve.

From Fig. 2 it is evident that molybdenum has a pronounced effect on the position and form of this curve. The curves do not show any pronounced difference for steels containing approximately 0.50-0.80% molybdenum. This may possibly be due to lower carbon and manganese contents of steel (4) as compared with steel (3). The dotted curve, however, suggests that in the higher molybdenum contents, pronounced changes in the temperature and the rate of transformation occur.

The maximum rate of transformation in the molybdenum steels studied occurred, at 850-900° F. It can also be seen that the initiation of austenite transformation is relatively rapid within the temperature range of 700-500° F. for the molybdenum series studied. This may be due to the lower carbon content of the molybdenum steels. The conclusion might be drawn at this point, that molybdenum displaces the nose of the curve in the direction of increasing time, thereby decreasing the critical cooling rate necessary for full hardening. It is undoubtedly this action of molybdenum which accounts for the remarkable depth-hardening effect which it has in steel.

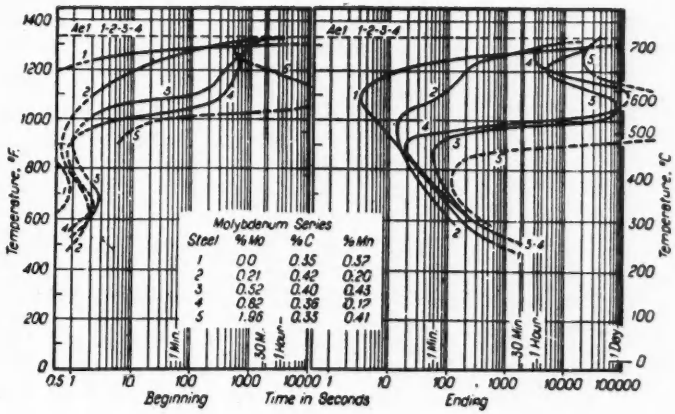


Fig 2.

Influence of Molybdenum on the Isothermal-Reaction-Rate-Curve.

The reaction-rate curves may be used in applying any type of heat-treatment providing the cooling rate of the particular section is known. The curves give the time required for austenite decomposition at subcritical temperatures, and by super-imposing the cooling curve it is possible to predict the hardness and micro-structure regardless of whether the part is quenched in air, oil, water, or any other selected hardening medium.

THE TREATMENT OF CARBONYL-NICKEL POWDER IN MELTING PROCESSES IN THE GERMAN IRON AND STEEL INDUSTRY

By PETER AZMAN and LEO SCHLECHT. (From *Stahl und Eisen*, Vol. 60, No. 11, March, 1940, p. 226).

ACCORDING to this process, raw materials containing nickel are treated under high pressure with carbonoxide, producing volatile carbonyl-nickel. From this a very pure nickel powder is processed. Many large scale experiments were carried out in Germany with the nickel powder thus obtained, extending the field of producing structural steel, corrosion and wear resistive steel, heat resistive chromium-nickel alloys, as well as cast iron containing nickel. In the following it will be discussed how the charging of the furnaces and the melting process is carried out, using carbonyl-nickel powder.

Structural Steel.

Melting is usually carried out in basic Siemens-Martin furnaces, basic electric furnaces or, for the production of high quality steel, in acidic electric furnaces.

The bottom of the furnace is first lined with a thin layer of scrap iron. Next, the furnace is charged with the nickel powder canned in sheet iron drums. The hot furnace gases are heating the nickel thoroughly and melt it to a solid mass. The rest of the scrap iron charge is put on top of the drums containing the nickel powder. It was found that with this method the whole of the nickel powder forms clicker, even if the sheet metal drums melt away. Melting is then finished in the usual way, the proper amount of nickel being added gradually.

Investigation proved that samples taken before tapping showed no irregularities or nickel losses. In the Siemens-Martin process it is possible to work up nickel powder with substances with high carbon content.

Before charging the furnace it is advisable to bake the nickel powder on the furnace for some time. Also in the rather rare cases where the sheet iron drums keep floating on top of the slag, and their content emptied in the fluid slag, no nickel losses were experienced.

To produce steel with a very accurate nickel-steel composition, electric furnaces are used. Charging is best carried out by inserting in the furnace the drums containing the nickel powder and baking them for some time, to avoid pulverization. The use of nickel powder ensures a very uniform nickel-steel alloy.

Corrosion Resistive Steel and Magnet Steel.

Recently these alloys are welded in induction furnaces with acidic charge. Here, too, the nickel powder charge is canned in sheet metal boxes, but it can also be charged freely if the slag is well covered. In small furnaces where the nickel charge is melted alone, scrap nickel is added (about one-third of the total charge). The lower the frequency of the furnace, the more important this becomes, since the current carrying capacity of the nickel powder, is rather low.

The employment of nickel powder was most successful, no drawbacks being encountered. It should be noted, however, that in these types of furnaces, the carbon content must not exceed about 1%.

Heat and Wear Resistive Chromium-Nickel Alloy.

Some troubles were experienced in this case. If nickel powder was used, cracks were observed during forging, and a suitable material for drawing thin wires could not be processed.

Since it is not recommended to melt chromium-nickel alloy with high nickel content in a new crucible, the furnace is first treated with a mixture less rich in nickel. After run-

ning off the charge, the next charge contains about one-sixth of scrap obtained from the previously melted mass, together with the same amount of carbonyl-nickel powder. This charge is covered with about 20 mm. deep slag (glass powder) and then melted. Presently, the slag is run off and the furnace is charged with some more nickel powder and covered with fresh slag. This is repeated until the total nickel powder required is charged in the furnace.

Then, the first de-oxydation is carried out by adding half the total amount of manganese charge, in the form of nickel-manganese. After removing the slag, the remaining constituents are added in a red hot state and, after melting, the slag is again renewed. The rest of the nickel-manganese charge is added subsequently until a properly melted mass is obtained, which can be readily forged.

It was found that the nickel-manganese charge could be kept at a considerably smaller value than for other types of nickel charge containing more sulphur. Thus, the strength and polishing properties of the finished metal have been improved.

Some special alloys, such as nickel-iron alloy, are produced from metal powders, e.g. carbonyl-iron powder and nickel-powder. Controlling the melting process these alloys show special physical properties.

No difficulties were experienced during the production of alloys of steel and nickel powder in oil heated reverbatory furnaces.

UNIPOLAR GENERATOR FOR LOW VOLTAGES AND HIGH CURRENTS

By M. ZORN. (From *Elektrotechnische Zeitschrift* (*E.T.Z.*), April, 1940, Vol. 61, pp. 358-60, 5 Figures).

(1) The history of the unipolar generator. FARADAY showed in 1831, that a D.C. voltage is induced in a permanent bar magnet, when it is rotated about its axis (Fig. 1). Noeggerath built in 1905 a D.C. machine without commutator by connecting induced conductors in series by aid of slip rings.* He succeeded in constructing a machine with an output of 300 kW at 500 V. Lamme achieved even a machine of 2,000 kW.† The great difficulties which had to be overcome when using brushes and slip rings for currents of many thousands amperes made the machines of the type of Noeggerath and Lamme disappear from the market.

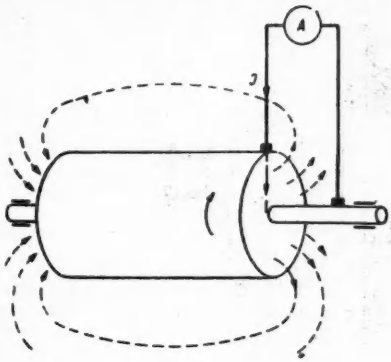


Fig. 1.
Faraday's Experiment.

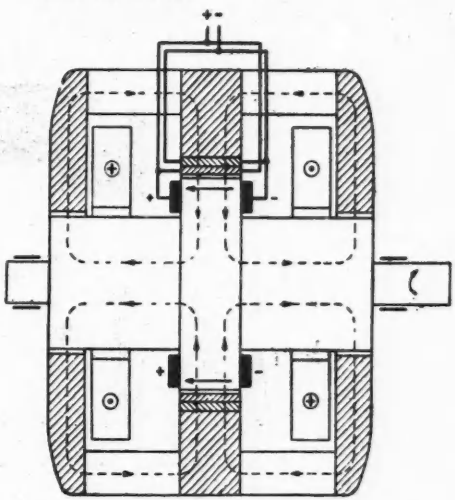


Fig. 2. Working function of Unipolar machine. Dotted lines: Lines of magnetic force.

*E.T.Z., 1905, p. 831.
†Proc, Amer. Inst. Electr. Engrs., 1912, June.

(2) The working function of the unipolar machine (Fig. 2).

When the rotor is rotated, E.M.F.s are generated, where lines of magnetic force enter or leave the rotor, i.e. at the gaps in the middle and at the end of the rotor. The polarity of the E.M.F.s depends on the direction of the lines of magnetic force and of the rotation. The value of the voltage difference between the brushes is :

$$E = \frac{d\Phi}{dt} 10^{-8} \text{volt} = \mathcal{L} l v . 10^{-8} \text{volt} = \frac{\Phi n}{60} . 10^{-8} \text{volt},$$

where

$\mathcal{L}$=magnetic induction in the air gap.
l=length of the rotor between the surfaces from which the current is collected.
v=peripheral speed of the rotor.
Φ=total magnetic flux through the air gap.
n=number of revolutions p.m.

If $\mathcal{L}$=11,000 Gauss, l=30 cm., v=4,500 cm./sec., then E $\backsim$ 15 volt.

(3) New types of unipolar generators.

The evolution of the chemical industry and the need for generators producing high currents of low voltage raised the interest for the unipolar machine on account of its low cost and its good efficiency. A unipolar machine giving 150,000 A at 7 V and 514 r.p.m., which was built a few years ago was of the same type as the machines constructed before the Great War. It had insulated conductors embedded in slots of the rotor and connected in series by slip rings. In 1930 Poirson produced a much simpler machine for 15,000 A, 7 V and 1,800 r.p.m. In 1937 he showed in the Palais de Découvertes at the Exhibition in Paris, a machine of the same new type, but of an even much greater output, i.e. 50,000 A, 14 V and 750 r.p.m. (Fig. 3). This machine has neither windings nor conductors in the rotor, the rotor itself forming the conductor for the current and replacing the slip rings too. The machine has several advantageous features. The construction is favourable good cooling. It is much easier to maintain the surface of the rotor in good condition for the collection of the current than to avoid wearing oval of slip rings. There are no losses caused by eddy currents. The brushes work smoothly on the solid rotor and are cooled effectively by convection of heat to the mass of the rotor. The construction is distinguished by great simplicity, and is, therefore, cheaper than previous types. All these advantages exist so long as the voltage to be generated is not higher than 20 volts, so that the simple construction of a rotor without any winding is applicable. Although the machines are heavier than the D.C. machines of the usual types, they are cheaper than these, because no costly material (copper) is used.

(*To be continued*)

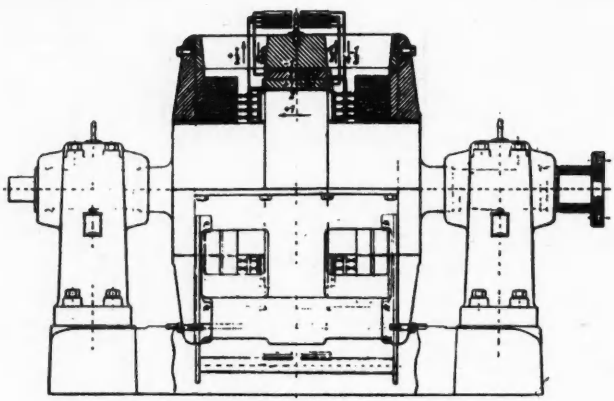


Fig. 3.
Unipolar machine of Poirson, for 50,000 A, 14 V, and 750 r.p.m.

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